New Scientist

WEEKLY 16 October 2021

TWISTED GRAVITY: EINSTEIN'S FORGOTTEN THEORY MAKES A COMEBACK

ENGINEERING GUT BACTERIA TO SPOT CANCER

SPIES PREPARE FOR QUANTUM COMPUTERS

THE EVERYTHING VACCINE

From cancer to HIV, how the pandemic has unlocked a medical revolution

EARLY BIRDS

China's feathered fossils rewrite the dinosaur story

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The anatomy of friendship

Friendship is both crucial to our well-being and extremely complicated: the demands it makes on the brain are so great that the number of friends we can have at any one time is limited to around 150. In this talk, Robin Dunbar will explain how our brains create friendships for us. Join us on 21 October at 6pm BST (1pm EDT).

newscientist.com/ns-events

Online

Covid-19 daily update

Stay on top of all the most crucial developments in the pandemic with our briefing, updated at 12pm BST every weekday. We round up the latest coronavirus news, and give links to exclusive features and interviews.

newscientist.com/coronavirus-latest

Podcast

Weekly

We begin with the news that, after 37 years of development, the first malaria vaccine has been approved. Then, Swedish author Andreas Malm argues that the climate movement needs to get more militant. Plus: a round-up of the physics and chemistry Nobel prizewinners, and the United Arab Emirates space mission launching in 2028 that plans to visit Venus and land on an asteroid orbiting beyond Mars.

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ALEXANDER MCNABB/UAE SPACE AGENCY

Asteroid encounter Probe hopes to be fourth to land on a space rock

CALTECH

Bird bot A robot inspired by birds could be used in rugged terrain

Video

Skateboarding robot

Watch how a bird-inspired robot with two legs and rotors for "wings" can skateboard, fly and walk along a slackline. The robot's creators say it could become a new tool to monitor infrastructure in hard-to-reach environments. Don't forget to subscribe to our channel for more discoveries, inventions and explainers.

youtube.com/newscientist

Newsletter

Lost in Space-Time

Sign up now to get Richard Webb's monthly dispatch on fundamental physics and cosmology. In the latest edition, he looks at the black hole information paradox, a puzzle that has been baffling us for almost 50 years, and the rumours that it may finally have been solved.

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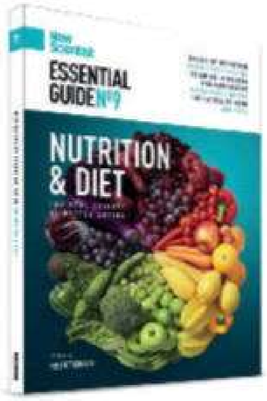
Newsletter

> "A paradox has puzzled us for half a century: what happens to information that falls into a black hole?"



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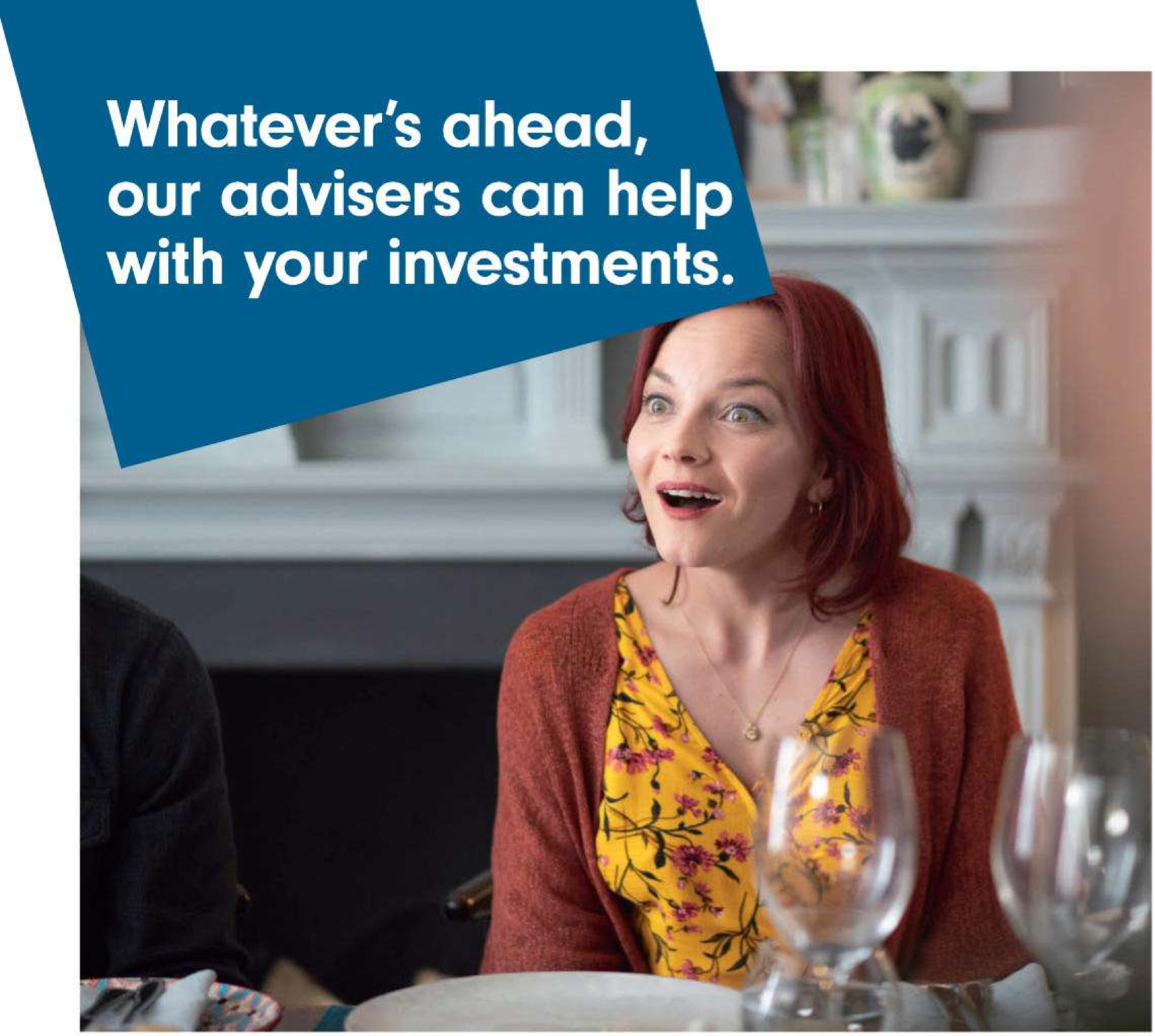

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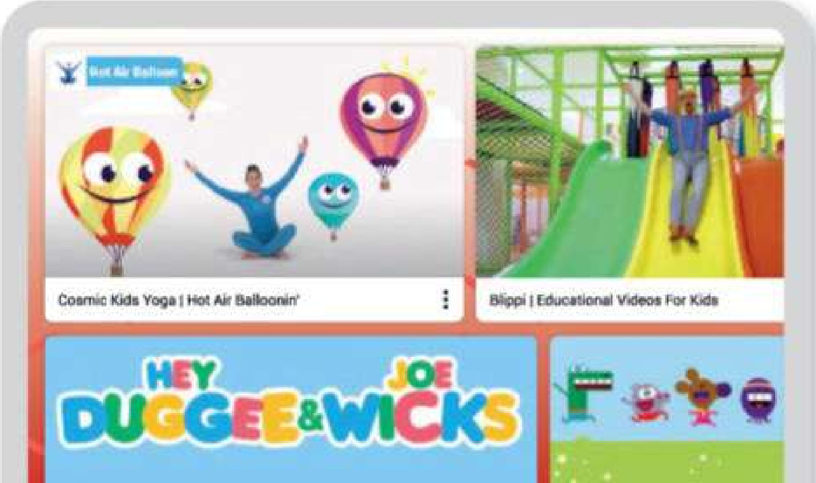
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HEY DUGGEE & JOE WICKS

An injection of hope

Out of the pandemic, a medical revolution is beginning

AMID the devastation of the coronavirus pandemic, there has at least been one piece of undeniably good news: the success of mRNA vaccines.

The Pfizer/BioNTech and Moderna vaccines were developed in record time and they have proved extremely effective. They are saving many lives, but this is just the start of something huge.

Using the same approach could help us develop better vaccines for many diseases, including conditions for which we have no inoculation at present. And when the next pandemic comes, we should be able to get more of the world's population vaccinated faster than we are managing this time.

Even more exciting is the potential of mRNA medicine to reach way beyond vaccines. mRNA technology is a way of getting our bodies to make any desired protein, the large, complex molecules that carry out most key tasks in our bodies. With vaccines, the mRNA – which is short for messenger RNA – provides instructions for making viral proteins to provoke an immune response.

But mRNAs can also code for human proteins for treating all kinds of disorders.

> **"mRNA technology is a way of getting our bodies to make any desired protein"**

As our feature on page 38 reveals, instead of injecting people with antibodies for treating infections, for instance, it should be possible to inject mRNA recipes for those antibodies. If people have inherited diseases caused by faulty proteins, mRNA can provide working versions. The possibilities are endless.

A growing number of drugs already consist of proteins, often antibodies, including the breast cancer drug Kadcyla (trastuzumab emtansine). Antibody drugs can be highly effective, but manufacturing proteins is difficult and time-consuming, which makes these drugs prohibitively expensive.

mRNA therapeutics promises to transform this by getting our bodies to do the hard part of making the protein. In a way, it is just a different method of delivering drugs, but the speed and ease of the process is revolutionary.

And with much more money now being poured into the field after the success of the coronavirus vaccines, that revolution is going to happen a lot faster than anyone thought possible. ▮

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New Scientist is published weekly by New Scientist Ltd. ISSN 0262 4079. New Scientist (Online) ISSN 2059 5387. Registered at the Post Office as a newspaper and printed in England by Precision Colour Printing Ltd

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BIANCA DE MARCHI/EPA-EFE/SHUTTERSTOCK

A mural in Sydney, Australia, on 11 October

Coronavirus

Sydney lockdown ends

People in Sydney can now go out and socialise after living under lockdown for 107 days, reports **Alice Klein**

RESIDENTS of Sydney in Australia can once more dine out and go shopping, now that more than 70 per cent of people aged 16 and over have been vaccinated. "I think it's the right time to start opening up," says Angela Webster at the University of Sydney. "We're already starting to see the effects of vaccination with case numbers falling quite steeply."

Sydney was locked down on 26 June to limit the spread of the delta variant, meaning people could only leave home for essential reasons like buying food. The rules were gradually tightened, limiting people's travel to 5 kilometres and introducing curfews in some areas, but delta's contagiousness meant that new daily cases continued to soar, peaking at 1599 on 10 September across New South Wales. Other parts of New South Wales have also had shorter lockdowns to contain smaller outbreaks.

The rapid spread of the virus in Sydney was partly enabled by Australia's initially slow vaccination rollout. On the first day of Sydney's lockdown, fewer than 9 per cent of adults in New South Wales had received both jabs. To incentivise vaccination, the New South Wales government promised to release Sydney from lockdown when 70 per cent of people aged 16 and over were fully vaccinated.

Now 90 per cent of this group have received one dose and 74 per cent have received two doses. About 68 per cent of children aged 12 to 15 have also received one jab since becoming eligible. Infections in New South Wales have dropped to below 400 per day.

As a result, restrictions were eased on 11 October. Fully vaccinated people in Sydney and their children can now have 10 visitors to their homes, meet in outdoor groups of 30 and visit hospitality venues and shops anywhere in Sydney. These venues must operate with limited capacity and compulsory mask-wearing if indoors. Schools will start to reopen on 18 October.

Once the state reaches 80 per cent vaccination in those aged 16 and over, fully vaccinated people will be allowed to have larger social gatherings and travel outside of Sydney. Restrictions on unvaccinated adults will be lifted on 1 December when New South Wales is predicted to have reached 90 per cent vaccination.

Infections are expected to rise, but the high vaccine coverage means that most people won't become severely ill, says Catherine Bennett at Deakin University in Melbourne.

Australia is coming into summer, which may also help to suppress case numbers thanks to time spent outdoors, says Webster.

In the state of Victoria, Melbourne has been locked down since 5 August due to a delta outbreak. The city has had six lockdowns during the pandemic, totalling more than 250 days – the most of any city in the world.

Case numbers are still climbing in Victoria – reaching a record 1965 on 9 October – but James Trauer at Monash University in Melbourne hopes they will start to fall soon. "We're getting very close to the level of vaccination that was enough for Sydney to turn things around," he says.

Australia's other states and territories currently have very few covid-19 cases and will keep their borders shut to New South Wales and Victoria until they hit their own vaccination targets.

The federal government recently announced that people will be able to go overseas again once each state and territory reaches 80 per cent vaccination of people aged 16 and over.

Webster believes border restrictions have helped keep Australia's covid-19 death toll relatively low, at just over 1400. "So far we've done incredibly well and have been very fortunate," she says. ▮

Coronavirus

UK response was 'serious' error

An authoritative report on the UK government's handling of the covid-19 pandemic has said that many thousands of deaths could have been avoided, reports **Adam Vaughan**

RICHARD POHLE-WPA POOL/GETTY IMAGES

Boris Johnson with advisers Chris Whitty and Patrick Vallance in 2020

THE UK government was wrong to wait so long to implement a lockdown in England at the start of the covid-19 pandemic and made a "serious early error" by adopting a "fatalistic approach" to how much it could slow the spread of the coronavirus, UK members of parliament (MPs) say in a report published this week.

Other failings highlighted include the "serious mistake" of stopping community testing in March 2020, an "often chaotic" test-and-trace system and "many thousands" of deaths that could have been avoided if people who had tested positive hadn't been sent from hospitals to care homes.

The UK was also too narrowly prepared for a flu-like pandemic, according to the joint report by the 22 MPs on the Health and Social Care Committee and the Science and Technology Committee. The analysis is the most authoritative view on the government's handling of the crisis to date, with a public inquiry not due to start until next year.

"It was a bit like Dickens's *Tale of Two Cities*: the best of times and the worst of times, the best of policy and the worst of policy," says Greg Clark, chair of the Science and Technology Committee. "You had the brilliance of the vaccine roll-out, scientifically and administratively. But then you had real failures such as the lack of testing."

UK prime minister Boris Johnson promised that England's test-and-trace scheme would be "world-beating", but it was hamstrung by inadequate capacity at the outset due to a lack of investment in public health for several years, says Clark. He says the system "seemed to stumble from crisis to crisis", was too centralised and failed to anticipate even predictable problems such as a spike in demand for tests in September 2020 as children returned to schools.

The MPs were highly critical of the government's response at the start of the pandemic, when Johnson appeared to pursue a strategy of "herd immunity", before a rethink in mid-March 2020 led to a lockdown. The report concludes there was "a degree of groupthink" among government officials and its science advisers, the Scientific Advisory Group for Emergencies (SAGE).

> "The idea you can wait for scientists to find the facts and then make a policy decision is a bit naive"

"Our criticism is there wasn't enough challenge to the official scientific advice. It's not to say there was anything deficient about the scientists concerned," says Clark. However, he says, people in government should have looked at how countries such as South Korea responded much faster, to challenge the UK view of only gradually imposing restrictions.

The UK government repeatedly said it would "follow the science" in its handling of covid-19, and the MPs conclude that it did until September 2020 – when it ignored SAGE's advice to implement a "circuit-breaker" lockdown. The committees say that decision is likely to have led to a faster spread of the Kent variant, later named alpha, in the winter.

Meanwhile, advice to the public was clear at the start of the pandemic but became "increasingly complex and harder to understand" when the first lockdown was lifted in May 2020. By contrast, the MPs hail the vaccine programme as being one of the most effective in the world for a country the size of the UK.

Asked how he views the UK's response overall, Clark says: "It was a mixed response. I think that was inevitable: you could never expect to get everything right."

Trish Greenhalgh at the University of Oxford says: "I think it's a 'warts and all' report. They're being quite brave there." She echoes the report, saying faster action should have been taken by the government on a precautionary principle rather than waiting for clearer answers from scientists. "The essential nature of a crisis is uncertainty, that's inherent. The whole idea you can commission a bunch of scientists to find the facts, wait for the facts and then make a policy decision is a bit naive."

However, she says, one big omission is that the report doesn't mention failings around face masks, such as England's deputy chief medical officer Jenny Harries suggesting they could be harmful.

Gabriel Scally at the University of Bristol, UK, says the report was right in its criticism of the early advice that SAGE had given, in part due to a lack of public health experts in early internal discussions. What is missing from the report is a focus on poor health and inequalities that existed before the pandemic, he adds.

Scally also believes the MPs are overly positive about the vaccine roll-out. After being the first country to begin administering doses, in December 2020, only 66 per cent of the UK population are now fully vaccinated, putting the UK behind Italy and Spain. "We've been overtaken by other European countries and our approach to vaccinating children has been shambolic," he says.

Stephen Griffin at the University of Leeds, UK, says one of the shocking elements of the report is that the UK's pre-pandemic efforts focused so much on flu, despite what he says were more "relevant exemplars" similar to covid-19 in South Asian countries.

A government spokesperson says: "Throughout the pandemic, we have been guided by scientific and medical experts and we never shied away from taking quick and decisive action to save lives and protect our national health system, including introducing restrictions and lockdowns." ▮

Cybersecurity

Spies may be gathering encrypted data to crack with future quantum computer

Matthew Sparkes

INTELLIGENCE agencies may be intercepting encrypted messages and storing them in the hope that they can eventually develop a practical quantum computer to crack them, a security researcher who has worked with the UK government has warned.

Although dozens of research groups are currently trying to build a practical quantum computer, none has yet publicly succeeded. Such a machine could quickly find the prime factors that serve as the multiplicative building blocks of a number – for example, 3 and 7 are the prime factors of 21.

This seemingly innocuous ability would fundamentally break encryption based on the difficulty of finding prime factors of large numbers, putting email, banking and cryptocurrencies at risk.

Researchers are already working on algorithms designed to keep data secure if this happens. But Andersen Cheng at cybersecurity firm Post-Quantum, who was a director at L3 TRL – a company supplying high-level encryption technology to the UK government, says that it could already be too late, as “harvest now, decrypt later” attacks are under way. This involves intercepting encrypted data and storing it ready for decryption once a quantum computer is developed.

Cheng points to instances when internet traffic has been routed on unusual global paths for no apparent reason before returning to normal, which are indicative of such attacks occurring. Often these errors have caused traffic within Europe and the US to be routed circuitously via Russia or China, at times through state-controlled telecommunications providers such as Rostelecom.

These relatively frequent errors could be accidental, but would also be the ideal way to select certain traffic and route it to a storage centre. Many key internet connections pass through Europe and the US, so similar attacks could occur there, says Cheng.

He believes these incidents were deliberate and that “the intelligence world has been collecting information, even though they cannot decrypt it today”. State secrets could still be invaluable years later, he says.

Exactly when quantum computers will threaten encryption isn’t clear, but Cheng says secret efforts may be ahead of public ones. “If you ask people in the public domain, they always say 10 to 20 years,” says Cheng. “If you ask the intelligence world… people are worried it will be below five years.”

Quantum computers could threaten today’s encryption systems

CREDIT

A leak by Edward Snowden in 2014 revealed the US National Security Agency had spent nearly $80 million pursuing a code-cracking quantum computer.

Daniel Dresner at the University of Manchester, UK, says that intelligence agencies have long held encrypted data while waiting for ordinary computers to advance enough to crack it. For example, the UK gathered encrypted German messages well before it had developed the means to decode them during the second world war.

There is no reason to believe the same isn’t being done today with an eye to quantum cracking, says Dresner. “They’re collecting stuff all the time, some of which will be decrypted and will be useful.”

A spokesperson for the UK’s National Cyber Security Centre says work is under way to design algorithms that are safe from quantum computers. “Certain sensitive information may still be of interest to adversaries in two or three decades,” says the spokesperson, meaning this work needs to be done now. ▮

Climate change

Breadfruit could be food of the future as climate warms

PLANTING more breadfruit trees could help make food supplies more stable as the planet warms, with climate models suggesting they will grow well across the tropics for many decades to come.

There is an especially big opportunity in tropical Africa, where large areas are suitable for growing breadfruit trees and will remain so until at least the end of the century.

Breadfruit is a bit like a potato that grows on a tree, says Lucy Yang at Northwestern University in Illinois. The starchy fruits can be cooked in many ways and also turned into a flour. “They are highly productive and extremely nutritious,” she says. “In addition, once a tree is established it is quite resilient.”

Yang and Daniel Horton, also at Northwestern, worked with Nyree Zerega at Chicago Botanic Garden to look at where in the tropics breadfruit grows now and to identify the climatic conditions cultivated trees require. Next, they used climate models to see where breadfruit could still be grown between 2060 and 2080.

They found that the crop will be relatively unaffected, with the overall suitable area shrinking by just 4 per cent globally (bioRxiv, doi.org/gz36).

“Areas today that grow breadfruit will continue to be able to grow breadfruit, although yields may decrease,” says Horton.

This is significant because some studies suggest the yields of staple crops such as rice could be hard hit by rising temperatures and more extreme weather. There are expected to be many more food shocks like that of 2010, when Russia stopped exporting wheat after a heatwave slashed yields.

> “Areas today that grow breadfruit will continue to be able to grow it, although yields may decrease”

The team’s findings also revealed a big opportunity in tropical Africa, where only a little breadfruit is currently grown. “There’s potential there to expand breadfruit cultivation,” says Horton. “This tree may be able to have really positive impacts on food resilience and security.” ▮

Michael Le Page

Renewables

UK National Grid in talks to build energy island in the North Sea

Adam Vaughan

UK COMPANY National Grid has revealed it is in talks with two other parties about building an "energy island" in the North Sea that would use wind farms to supply clean electricity to millions of homes in north-west Europe.

The idea of a renewable energy hub in the North Sea has been floated for years, but has yet to progress from studies to reality. The concept envisages offshore wind farms that have a much larger capacity than those in use today, with subsea electricity cables taking the energy to whichever country needs it most.

National Grid is a major developer of such long-distance cables in the region, most recently one from Norway to the UK, so its involvement in talks with other energy firms increases the chance of the idea being developed.

"We are in tripartite discussions over an energy island that the UK would likely connect to," says Nicola Medalova at National Grid. She wouldn't name the two other parties the company is talking to.

Other energy network operators around the North Sea have signalled their interest in building an energy island, including Elia in Belgium and TenneT in the Netherlands. Two years ago, TenneT concluded that such a project would be technically feasible, despite the engineering challenges. However, the company tells *New Scientist* that it isn't in "concrete" talks with National Grid about an energy island.

Belgium's energy minister, Tinne Van der Straeten, said in May that the country would build an island to "interconnect our wind turbines", built by Elia. A spokesperson for Elia says it is developing a second electricity interconnector cable between the UK and Belgium, but it is uncertain if it will be connected to the Belgian island.

Medalova says energy islands could either be built on an existing natural island or a purpose-made artificial one. "You put lots of different technologies, perhaps in one space – you could have wind, hydrogen, battery storage, all the rest of it, and that can be connected to one country, two countries," she says. The project being discussed is looking at "three connection points", she says, an indication that three countries are involved.

Kees van der Leun at Netherlands-based consultancy Common Futures says: "Connection via an energy hub between the UK and the Netherlands and Belgium... would certainly add value. This is because of the massive buildout of offshore wind in the UK, and the time difference in wind peaks between the UK and the continent."

Whichever countries the island is connected to, they could all take advantage of the low-carbon energy generated by hundreds or even thousands of turbines. The energy island could be built before 2030, says Medalova, which would give a huge boost to the promise that UK prime minister Boris Johnson made last week of an entirely green national electricity grid by 2035. ▮

An existing offshore wind farm in the North Sea

MISCHA KEIJSER/GETTY IMAGES

Robotics

Brain in a box helps robots navigate like insects do

A SYNTHETIC, insect-inspired "brain" can guide a robotic dog using much less energy and weight than conventional approaches require.

The control system, built by UK start-up Opteran Technologies, mimics how honeybees and other insects navigate. It contains a computer chip and two cameras, which provide a 360-degree view, and can be connected to various robots and drones.

The package weighs only 30 grams and draws less than 3 watts of electricity. That is a fraction of what is required by most robot control systems, says Opteran CEO David Rajan. "Our algorithms are so lightweight that we can run them on tiny chips, and they run tremendously fast as well," he says.

The company's technology builds on the research of James Marshall at the University of Sheffield, UK, who is also Opteran's chief scientific officer. Using a combination of behavioural studies and recordings of neural activity, his team reverse-engineered the brain circuits insects use in navigation.

The software that runs on these is similar to the neural networks used by artificial intelligence, says Marshall. But rather than learning how to solve tasks by training on lots of data, it is hardwired to mimic the brain structures responsible for insects' innate navigational abilities.

The researchers have now shown that a pair of their algorithms can guide a robot dog through a maze of cardboard boxes. The first one stitches together input from the cameras to create a stabilised, panoramic view. The second one mimics how insects analyse optical flow – essentially motion in a visual scene – to estimate velocity and avoid collisions.

Opteran is also working on algorithms that let robots map their environment and make decisions by weighing up different objectives. The company's technology is being tested by several clients, including for operating delivery drones and inspection robots in mines. ▮

Edd Gent

"Using behavioural studies and recordings of neural activity, they reverse-engineered brain circuits"

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Wildlife

Toxic moth is threat to UK trees after failure to halt spread

Gary Hartley

THE oak processionary moth (OPM), an invasive species in northern Europe with caterpillars that are toxic to humans and other animals, expanded its range at an increased speed in the years following its arrival in the UK, despite government efforts to contain it.

DENNISVDW/GETTY IMAGES

Oak processionary moth caterpillars can damage the trees they live on

Yevhen Suprunenko at the University of Cambridge and his colleagues looked at data on larval nests of the OPM (*Thaumetopoea processionea*) across south-east England to model a 13-year shift in the moth's range.

They found that, following the first discovery of OPM caterpillars in the UK in 2006, the species expanded the radius of its range slowly until 2014, at 1.66 kilometres per year on average. But in the five subsequent years, there was an abrupt increase to a much faster rate of 6.17 kilometres per year on average.

Suprunenko and his team cite limited resources for monitoring the growing population and changes in habitat quality as probable factors in this shift (*Agricultural and Forest Entomology*, doi.org/gz9w).

Mistakes may have been made at the start of the moth's invasion, says David Slawson at Imperial College London, who wasn't involved in the research. "There was a delay before commencing intensive surveillance and destruction of infested trees," he says. "Since then, as confirmed by results in this paper, it has continued to spread despite control measures."

Health

Living sensors in our guts could warn of early cancer

Michael Le Page

AN ENGINEERED bacterium in the gut of an animal has successfully detected the presence of a specific DNA sequence for the first time. The approach could be used to create living sensors that provide early warnings of cancers or pathogens.

"It is perfect for the detection of cancer and precancer throughout the entire gastrointestinal tract," says Jeff Hasty at the University of California, San Diego.

Many groups are developing various kinds of biosensors for detecting chemicals, but ones that could spot specific DNA sequences would be extremely versatile and could have all kinds of potential uses. Hasty says this approach could also be used to detect cholera in drinking water sources, malaria in waters where mosquitoes breed and toxic fungi on crops.

In the gut, bacteria could even be designed to treat infections that they detect, says Hasty. "The list of [intestinal] infections that could be detected and thwarted by an early response are vast."

To create their DNA detector, Hasty worked with Daniel Worthley at the Colonoscopy Clinic in Brisbane, Australia, and others to exploit two things.

Firstly, many bacterial species actively take up DNA fragments from the environment. They typically do this to use the DNA as a food source, but when the imported DNA matches part of the bacterial genome, the imported sequence can get integrated into it.

Secondly, most bacteria also have CRISPR immune systems that can target and destroy specific DNA sequences – CRISPR gene editing uses components from these bacterial systems.

The researchers engineered a bacterium called *Acinetobacter baylyi* to detect a single-DNA-letter mutation in a human gene called KRAS, found in many cancers. They first programmed the bacterium's CRISPR machinery to chew up any normal copies of KRAS that it took in, so only mutant sequences could be integrated into the bacterial genome.

Next, they ensured that if any mutant KRAS sequences were integrated, this would make the bacteria antibiotic resistant. The researchers then added the bacteria to the guts of mice, some of which had colorectal tumours containing the mutant KRAS gene.

1

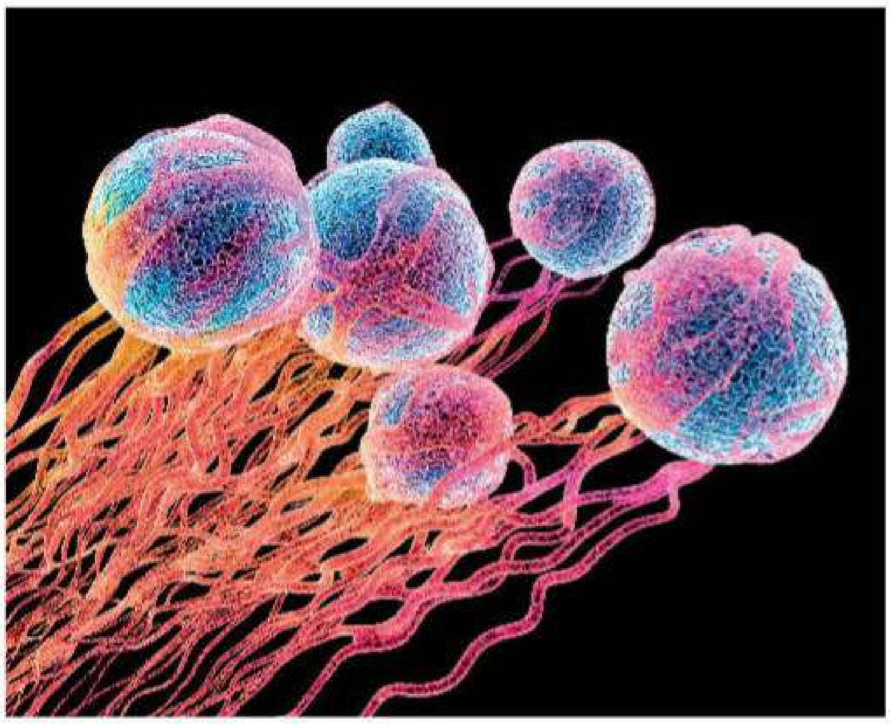
The bacteria respond to a single DNA mutation found in cancer

When faecal samples from mice were put on a medium containing an antibiotic, only *A. baylyi* from the rodents with tumours grew and became visible (bioRxiv, doi.org/gz38).

"To my knowledge, this is the first example of bacteria being engineered to detect specific DNA sequences while living in the gut," says David Riglar at Imperial College London, who wasn't involved in the research. "It's always exciting to see advances such as this one."

Simply sequencing the DNA present in faecal samples isn't a reliable way to detect gut cancers or pathogens early on, says Hasty, because our guts are full of enzymes that rapidly chew up any free DNA. But if the DNA detection happens in situ in the gut, it can be done before the DNA is destroyed.

The antibiotic-resistance-based detection system was used for proof of principle, he says. The team is working on ways to make it simpler to tell when the bacteria have encountered a target molecule.


ALFRED PASIEKA/SCIENCE PHOTO LIBRARY

Signs of cancer cells like these could be detected via bacteria

Environment

Decaying tanker threatens disaster

If an oil tanker in the Red Sea spills its oil, it will lead to a humanitarian crisis in Yemen

Graham Lawton

A HUGE abandoned oil tanker anchored off Yemen could unleash a catastrophic oil spill in the Red Sea, bringing starvation and death to the region.

The tanker, called Safer, is about 9 kilometres off Yemen. It is owned by Yemen's national oil firm, which once used it to store crude oil, but abandoned the ship in March 2015 after it was captured by Ansar Allah, a rebel group known as the Houthis who are combatants in Yemen's civil war.

Safer hasn't been inspected or maintained since 2015. It was built in 1976 and should have reached the end of its working life in 2016, but is still afloat with around 150,000 tonnes of oil in its fragile single hull. It is visibly dilapidated and "continues to deteriorate", says Benjamin Huynh at Stanford University in California. A giant oil spill is increasingly likely, he says.

A team led by Huynh modelled the public health effects of such a spill. "We're looking at a potential humanitarian catastrophe: millions without food or clean water, outbreaks of waterborne illness and mass hospital shutdowns due to lack of fuel," he says.

Around half of Yemen's 30 million people depend on food aid, 68 per cent of which arrives through two Red Sea ports, Salif and Hudaydah. An uncontained spill would close both within days and keep them closed for weeks. Up to 8.1 million people wouldn't receive food aid for the duration. If the spill spread into the Gulf of Aden that number could rise to 11.9 million, according to the modelling (*Nature Sustainability*, doi.org/gz9s).

A spill would also shut down the Red Sea fishing industry, which provides subsistence for a further 1.7 million people. Yemen is already on the brink of famine, says Huynh.

Desalination plants that supply more than a million people with drinking water would be disrupted too. Many other Yemenis rely on groundwater pumps and water trucks, which require fuel. Yemen imports more than 90 per cent of its fuel, and previous port closures have led to severe shortages.

Air pollution from a spill, especially if it caught fire, would also cause respiratory and cardiac illness. In the worst-case scenario in the modelling, this would increase hospitalisations by 42 per cent. Port closures would hamper the supply of medicines, and fuel shortages could force hospitals to close.

2020 MAXAR TECHNOLOGIES/GETTY IMAGES

Safer, an ageing oil tanker moored off the coast of Yemen in the Red Sea

This would add to existing stresses on healthcare due to economic issues, epidemics and the covid-19 pandemic. In May, the UN said that Yemen's health system had collapsed.

"If the Safer breaks up, of course they cannot cope with that," says Jens Laerke at the UN Office for the Coordination of Humanitarian Affairs. "The Yemen health system is already in shambles, to put it bluntly."

Previous port closures caused by blockades led to a breakdown of the water and sewage systems, rubbish collection and electricity supplies, all of which contributed to a cholera outbreak in Yemen, which peaked in 2017.

There is a simple solution to the impending disaster, says Huynh: get the oil off the ship. But there is no plan to do so. In 2020, the Houthis gave the UN permission to board the tanker for inspections and repairs. The visit was set for January, but is delayed indefinitely after relations broke down.

The UN and its specialist agency, the International Maritime Organization, say they are helping Yemeni authorities to plan an emergency response, but the ongoing civil war makes it extremely difficult. ▮

Biology

Circadian clock made in lab to probe biological rhythms

FOR the first time, a cellular pacemaker – or circadian clock – has been built outside a living organism.

The clock, copied from a cyanobacteria, was devised by Carrie Partch at the University of California, Santa Cruz, and her colleagues. It is made from six proteins and can work without any human intervention for several days. "I think the record we've got so far is two weeks," says Partch.

Circadian clocks regulate the timing of the activity of an organism's various cellular systems. In cyanobacteria, they usually work on a 24-hour light cycle.

"By forming this clock outside of a living organism, we can more closely analyse certain aspects of the process," says Partch.

The team was also able to monitor the rhythms within cyanobacteria by fluorescently tagging the proteins to get real-time data on their timekeeping.

Using this method and by adding mutations to the test-tube system that turned off certain parts of the clock, the researchers discovered that two of the proteins, called SasA and KaiB, are far more influential than previously thought.

"We'd previously believed that SasA was just an amplifier of the clock – it kept everything robust," says Partch. "But we found that, in fact, its main function is to recruit one of the clock's core proteins, KaiB."

The team wouldn't have been able to discover this by just looking at the clock in a living organism, she says (*Science*, DOI: 10.1126/science.abd4453).

> **"By forming this clock outside of a living organism, we can more closely analyse it"**

The next step is to determine how the clock trains itself to the 24-hour cycle in the first place, says Partch.

"They've managed to extend the in-vitro cyanobacteria clock to include effects on transcriptional output [which affects gene expression]," says Amita Sehgal at the University of Pennsylvania, noting that the clocks of more complex organisms like humans work via this system too. ▮

Jason Arunn Murugesu

Early lifex

Lava-munching microbes were among the earliest living things on land

Michael Marshall

VOLCANOES may have helped early microscopic organisms to colonise the land. The oldest known land-dwelling microorganisms lived in estuaries close to erupting volcanoes, which may have provided them with essential nutrients.

"This sedimentary environment interacting with the volcanic environment created the perfect conditions for life to spread," says Deon Janse van Rensburg at the University of Jena in Germany.

Long before animals and plants, the only life on Earth was single celled. Janse van Rensburg and his colleagues studied fossil microbes from 3.2 billion years ago that were found in the Moodies Group geological formation in the Barberton Greenstone Belt, South Africa. The belt's fossils include some of the oldest examples of microorganisms living on land. "This is a huge area where you find almost continuous [fossil] microbial mats in [what was] a tidal environment and a shoreline environment," says Janse van Rensburg.

The team focused on a little-studied section of the Moodies Group called the Moodies Igneous Complex. This contains preserved lavas and other substances ejected from volcanoes.

The combination and placement of the rocks revealed that the volcanoes erupted onto the plain of an estuary. Once the lava had cooled and solidified, water flowed over it and eroded it. Microbes lived in sheets called mats on and near the newly formed rocks, and Janse van Rensburg's team think the volcanoes provided heat and energy-rich chemicals that the microbes could feed off (*Precambrian Research*, doi.org/gzr2).

The Barberton region of South Africa as it appears today

FRIEDRICH VON HÖRSTEN/ALAMY

"It is certainly possible that, in a volcanic environment interacting with terrestrial shallow water deposits and [microbial structures called] stromatolites, there was hydrothermal interaction with life," says Tara Djokic at the Australian Museum in Sydney. There are plenty of modern analogues, she says. "We see microbial life thriving in hot springs [and] living off chemical energy in and around hot vents."

The next step is to find out more about exactly how the microorganisms lived. Over the next few months, the International Continental Scientific Drilling Programme will drill into the rocks of the Moodies Group. This should yield more information about conditions at the time and the metabolic strategies used by the microbes, says Janse van Rensburg.

The wider issue is how to interpret the fossils in the context of the early history of life. Janse van Rensburg thinks the Barberton fossils show the type of place where microorganisms first moved onto land, after originating in the sea.

However, in recent years, Djokic and her colleagues have published evidence that parts of what is now Australia were above water 3.5 billion years ago, hinting life may have found its way onto land earlier than 3.2 billion years ago. ▮

Palaeontology

Some ancient giant ground sloths added meat to their diet

GIANT ground sloths have often been portrayed as gentle giants of the ice age. But now there is evidence that some of these creatures had more cosmopolitan tastes that incorporated flesh.

The crucial clues come from isotopes of nitrogen tied to particular amino acids preserved in the fur of Darwin's ground sloth, *Mylodon darwinii*, an approximately 3-metre-long animal that lived in South America between about 1.8 million and 12,000 years ago. These geochemical signals act as a proxy for diet, as nitrogen isotopes from what an animal eats become incorporated into the tissues in their bodies, in this case hairs that remained intact for thousands of years.

Different plants and animals have different nitrogen signatures, and palaeontologist Julia Tejada at the University of Montpellier, France, and her colleagues discovered that Darwin's ground sloth was an omnivore (*Scientific Reports*, doi.org/gzq2).

The results dovetail with what zoologists have come to understand about living sloths. "Two-toed sloths are omnivorous so it's not too hard to imagine similar diets in some giant ground sloths," says Melissa Macias, a giant sloth expert at Applied EarthWorks, a cultural resource management company in California.

The key will be finding additional fur samples that allow more species to be examined using the new technique. "It would be interesting to see where other sloths would fall on the omnivory to herbivory spectrum," says Macias, as general anatomy alone can only go so far in revealing an extinct creature's diet.

> "Two-toed sloths are omnivorous so it's not hard to imagine similar diets in some giant ground sloths"

Realising that some giant ground sloths regularly consumed meat alters what researchers expect of ancient ecosystems, Tejada's team writes. Palaeontologists have previously noted a seeming lack of meat-eating species in prehistoric South America – a role that giant sloths may have helped fill. ▮

Riley Black

Space exploration

NASA spots odd pairs of asteroids in deep space

Leah Crane

THE New Horizons spacecraft has spotted two pairs of small asteroids called "tight twins" on the outer edges of our cosmic neighbourhood. These objects may help us understand how planets were formed in the early solar system.

The members of these pairs of asteroids are so close together that we could never tell from any Earth-based telescope that they consist of two separate objects.

"To make these observations, we had to press the highest-resolution camera on the spacecraft… and the spacecraft itself, to their limits," said Hal Weaver at Johns Hopkins University in Maryland, who presented this work at a virtual meeting of the American Astronomical Society's Division for Planetary Sciences on 6 October.

The two asteroid couples are called 2011 JY31 and 2014 OS393. The spacecraft took hundreds of images of each object, revealing that the asteroids that make up 2011 JY31 are each about 50 kilometres across, and they are separated by a bit less than 200 kilometres. The ones that make up 2014 OS393 are about 30 kilometres across and are some 150 kilometres apart.

New Horizons hurtled by Pluto in 2015 and passed close to another distant space rock called Arrokoth in 2019, and continues to explore a region of the solar system called the Kuiper belt. These latest asteroids are part of a population called the cold classical Kuiper belt objects (KBOs), some of the most primitive rocks in the solar system.

Including these two sets, we have now observed three cold classical KBOs up close, the third being Arrokoth. "Two out of the three are tight twins, which is remarkable and may be telling us something important about the planetesimal formation in the outer solar system," said Weaver. ▮

Analysis Child health

How does poverty affect children's health?

Benefit cuts are likely to impact children in many ways, but we are only beginning to understand how, reports **Jason Arunn Murugesu**

SALLY ANSCOMBE/GETTY IMAGES

CUTS to benefits in the UK are expected to push hundreds of thousands of extra children into poverty. The UK government's weekly £20 top-up to Universal Credit payments, intended as a support measure during the pandemic, ended on 6 October – a move that is expected to lead to a further 290,000 children falling below the poverty line, according to the Legatum Institute think tank in London.

Poverty is defined by the UK government as living in a household that makes less than 60 per cent of the country's median annual income. The threshold is currently £17,994. Around 3.2 million children were below this line in 2020 – about 23 per cent of children in the country.

"We know child poverty has a massive effect on health," says David Taylor-Robinson at the University of Liverpool, UK. Research shows that poorer children in the UK are more likely to have asthma and obesity, and more likely to develop stomach cancer as adults. Food insecurity as a child has also been linked to chronic illnesses such as cardiovascular disease later in life.

There are other wide-reaching effects, too. Children from poorer families are more likely to begin school with worse literacy skills and develop mental health conditions when older. The poorest teenagers attend hospital accident and emergency departments 70 per cent more often than the richest.

The UK government hasn't carried out a formal risk assessment of what the effect of the cut to Universal Credit will be. A spokesperson for the Department for Work and Pensions told *New Scientist* that this wasn't necessary because the top-up was meant to be temporary.

23%

of UK children were living below the poverty line in 2020

But an analysis by Taylor-Robinson and his team, which is yet to be published, suggests the cuts will result in 1500 more children being taken from their families and put into care by social services over the next year.

We are only just starting to figure out the mechanisms behind the effects that poverty has on children's health. "A lot of it will come down to poor nutrition," says Jack Shonkoff at Harvard University. But he also says that a persistently activated stress system has a major role in the biology of poverty. Children who grow up around parents or other caregivers who are stressed about money are likely to grow up stressed too, says Shonkoff.

Stress due to poverty makes it hard to benefit fully from schooling

"This stress leads to a persistent elevation of inflammation, which affects the immune, metabolic and cardiovascular systems," he says. "It also disrupts developing brain circuits, some of which are related to a child's ability to focus, the ability to control their impulses." These are important for doing well in school, he says.

The effects make it harder for these children to reap the full benefits of school and extracurricular activities. "If we had policies that targeted this stress, maybe these children would be slightly better off," says Shonkoff.

This is pertinent at a time when schools in the UK are trying to make up for the school closures and disrupted teaching of the pandemic, which have disproportionately affected children from less wealthy households.

"It is clear [government welfare] policies are not built around science," says Taylor-Robinson.

The Department for Work and Pensions spokesperson told *New Scientist* that the payment top-ups were "designed to help claimants through the economic shock and financial disruption of the toughest stages of the pandemic, and they have done so". ▮

Technology

Deepfake voices can fool humans and smart assistants

Chris Stokel-Walker

FREELY available software that can mimic a specific individual's voice produces results that can fool people and voice-activated tools such as smart home assistants.

Security researchers are increasingly concerned by deepfake software, which uses artificial intelligence to alter videos or photographs, for example by mapping one person's face onto another.

Emily Wenger at the University of Chicago and her colleagues wanted to investigate audio versions of these tools, which generate realistic English speech based on a sample of a person's voice. They were prompted by reading about such technology being used to scam €220,000 (£187,000) from a UK-based, German-owned firm in 2019.

63%

Proportion of successful attempts at spoofing Alexa

Voice commands are now used to control digital home assistants like Amazon's Alexa, as well as some automated phone systems run by businesses such as banks. "We wanted to look at how practical can these attacks be, given that we've seen some evidence of them in the real world," says Wenger.

She and her colleagues used two deepfake voice synthesis systems, downloaded from the popular GitHub code repository, to mimic voices. One system, AutoVC, requires up to 5 minutes of speech to generate a passable imitation of the target voice, but the other, SV2TTS, only requires 5 seconds. "We wanted to target the low-bar attacker mindset," says Wenger.

They used the software to try to unlock speaker recognition security systems used by Microsoft Azure, WeChat and Amazon's Alexa system. Azure's voice-recognition system is certified by several formal industry bodies, WeChat allows users to log in with their voice and Alexa enables people to use their voice to make payments in third-party apps like Uber.

AutoVC was able to fool Azure around 15 per cent of the time, while SV2TTS managed 30 per cent. Azure requires users to speak trigger phrases to authenticate themselves, and the team found that SV2TTS could successfully spoof at least one of 10 of these common phrases for 62.5 per cent of the people the researchers tried, suggesting a persistent attacker would have a higher chance of breaking through with SV2TTS.

Given its lower performance, the team didn't try AutoVC against WeChat and Alexa, but SV2TTS successfully fooled both systems about 63 per cent of the time (arxiv.org/abs/2109.09598).

Results varied, but deepfakes did better at spoofing women's voices and those of non-native English speakers. "Why that happened, we need to investigate further," says Wenger.

Microsoft declined to comment, while WeChat didn't respond to *New Scientist*'s request to comment. An Amazon spokesperson said: "Alexa is built with multiple layers of privacy and security designed to keep customer information safe."

The deepfake voices didn't only succeed against computer systems. In a separate test, the team asked 200 people to say whether voices were fake or real, with the fakes fooling them around half the time.

"The realism and accessibility of voice synthesis is only going to improve, bringing with it profound implications for the cybersecurity landscape as our voices increasingly become biometric keys to our digital lives," says Henry Ajder at Metaphysic, a firm developing tools for deepfakes. ▮

Voice assistants such as Alexa can be fooled by AI

BILL O'LEARY/THE WASHINGTON POST VIA GETTY IMAGES

Marine biology

Sea cucumber genes harbour secrets of survival in the deep

Michael Marshall

A SEA cucumber that lives in extreme deep-sea environments has had its genome sequenced. This revealed that many of its genes have been altered, potentially by the intense places it calls home.

***Chiridota heheva* is a sea cucumber, a worm-like animal in the echinoderm group that also includes starfish. First described in 2004, it is one of the only echinoderms that lives in three of the most extreme ocean locations: hydrothermal vents, cold seeps rich in carbon-based chemicals like methane, and "whale falls" – the sunken corpses of whales. These places have little dissolved oxygen and are toxic to many organisms.**

To find out how *C. heheva* survives, researchers led by Muhua Wang at Sun Yat-sen University in China read its DNA from samples collected by team member Jian He in the South China Sea in 2019.

The team found that 27 genes had been strongly selected for, suggesting they evolved in response to environmental pressures. Four of them are known to be involved in surviving a lack of oxygen (bioRxiv, doi.org/gzsj). Some genes had also been duplicated. There were seven genes for aerolysin-like proteins that are usually part of the immune system. Most echinoderms have either just one or none of these.

These proteins create small holes in the outer membranes of bacteria, destroying them. However, Wang says cold seeps don't normally have any infectious bacteria. "We don't think it's related to the immune system," he says.

The sea cucumbers could instead use the proteins to help digest bacteria. This would make sense because, unlike most animals in these environments, *C. heheva* doesn't have symbiotic bacteria that provide it with nutrients. However, Wang emphasises that this idea is only a hypothesis at present. ▮

Fertility

Pregnancy is rarer after concussion

Women's chances of becoming pregnant drop in the years just after a head injury

Jason Arunn Murugesu

IN THE two years after a concussion, women are less likely to become pregnant than women who injure other parts of their body.

To study the effects of concussion on pregnancy, Martina Anto-Ocrah at the University of Rochester in New York and her colleagues recruited 102 women with concussion and 143 women who had other injuries that required a visit to a Rochester emergency room.

The participants were all aged between 18 and 45 and those with concussion all had head injuries from vehicle crashes. Those without concussion were only recruited if they had an injury serious enough to warrant an X-ray but hadn't broken any bones. "We wanted there to be a psychological parallel between these injuries and those who had suffered a concussion," says Anto-Ocrah.

No participant had a history of being subject to domestic violence, so the researchers could focus on any effect from a single injury.

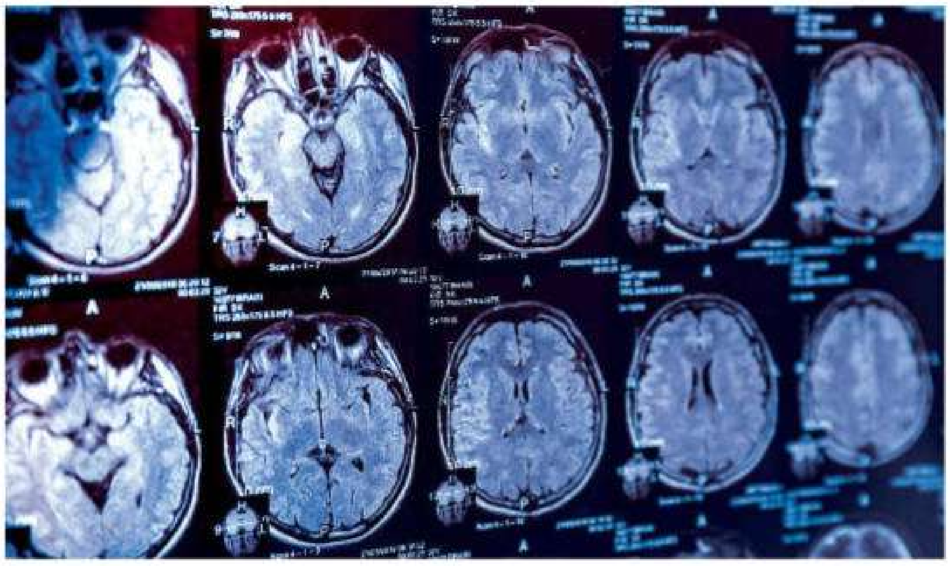
The team found that across the 24 months after injury, concussed women had a 76 per cent lower rate of pregnancy than the study's other participants, even when taking into account ethnicity, education, use of birth control and obstetric history (*Journal of Head Trauma Rehabilitation*, doi.org/gzsc). Those who reported sexual dysfunction six to 10 weeks after their concussion had an 84 per cent lower pregnancy rate.

"I was not surprised by the results," says Anto-Ocrah. "We know that concussions affect menstruation and can cause sexual dysfunction in some women – it only makes sense that this would affect pregnancy rates also."

Concussion can affect menstruation and lead to depression

She says there may be several reasons. "There's definitely a big psychosocial dimension," she says, noting that concussion can lead to depression and make people less likely to want to be intimate with someone.

Beyond that, concussion can also affect hormones key to pregnancy. "What happens is that hormonal regulation gets a little bit wonky," says Anto-Ocrah. "Your progesterone and oestrogen levels get dysregulated, for example."


PIXEL-SHOT/ALAMY

The researchers didn't consider whether the women intended to get pregnant, and Anto-Ocrah says the next step is to specifically look at people wanting to get pregnant who also suffer a concussion.

Anthony Kontos at the University of Pittsburgh in Pennsylvania says not accounting for intent to become pregnant is a limitation, but says "the findings support the potential impact of concussion on female reproductive health outcomes".

"Moving forward, researchers should examine other factors that might be associated with the reported relationship between concussion and pregnancy, such as psychological stressors, as well as the timing of concussion with regard to age and hormone cycles," he says.

Anto-Ocrah says a lot of the issues that women face after a concussion are probably overlooked. She says there is a taboo about discussing any effects on sex lives after such incidents. ▮

Robotics

Flying and walking robots claim cave rescue prize

A TEAM of robots has claimed a $2 million prize for successfully exploring an underground complex as part of a competition run by the US Defense Advanced Research Projects Agency (DARPA).

DARPA regularly holds contests to encourage fledgling technologies, most notably with self-driving cars – several teams that entered a DARPA challenge in 2005 went on to start companies in the industry.

This latest event, which took place at the Louisville Mega Cavern in Kentucky last month, tasked robots with searching for specific items in a simulation of an underground rescue operation, including a dummy, a backpack and a cellphone.

The robots had to be able to operate in environments that are too dangerous for human rescuers, with risks like fire, smoke, toxic gas and unstable structures. Being underground limits communications, so search robots needed to be highly autonomous.

The winning team, Cerberus, used a mixture of ANYmal quadruped robots and flying drones to map out the space and locate 23 of the 40 items, beating seven other competitors.

"Legged robots offer endurance but simultaneously highly capable locomotion to negotiate difficult terrain and stairs," says Cerberus team leader Kostas Alexis at the Norwegian University of Science and Technology. "Flying robots are needed when high vantage points or fast exploration are required. Thus the combination covers all needs."

"Legged robots offer endurance and highly capable locomotion to negotiate difficult terrain"

Alexis says the Cerberus team used guided autonomy, in which a human operator juggles several robots, sending each out to a particular area. Once instructed, a robot autonomously explores as much of the specified area as possible in the given time before returning to communication range.

The core technology behind the robots is mature enough to use for mine inspection and search-and-rescue operations, says Alexis. ▮

David Hambling

Wildlife

Hares with failed snow camouflage still dodge predators

Krista Charles

SNOWSHOE hares, which live in Canada and northern parts of the US, turn white in autumn when snow usually begins to fall in their environment. The animals may become mismatched and lose their camouflage if snowfall is delayed – but, surprisingly, such white hares have a lower risk of being eaten than the matched brown ones.

Joanie Kennah at the Memorial University of Newfoundland in Canada and her colleagues captured and monitored 347 snowshoe hares (*Lepus americanus*) in south-west Yukon, Canada, for three autumns and four springs between 2015 and 2018. About one in seven captured hares were mismatched.

The researchers found that the autumn mortality risk of the mismatched hares was 86.5 per cent lower than that of the matched ones. This may be because snowshoe hares gain more insulation when they turn white, so the mismatched white hares might have an advantage over brown hares when it comes to their energetic demands.

Evidence in favour of this idea came from accelerometers fitted to the hares. These showed that mismatched snowshoe hares foraged for 17 to 77 fewer minutes per day than matched brown hares and so decreased their risk of predation (bioRxiv, doi.org/gzqp). ■

A snowshoe hare in Yukon, Canada, in the process of turning white for winter

SHUTTERSTOCK/JUKKA JANTUNEN

Analysis AI regulation

European Union moving towards AI clampdown

The use of artificial intelligence in law enforcement could be heavily restricted in the EU – but not in the UK, says **Matthew Sparkes**

THE European Union has taken a further step towards banning the use of artificial intelligence to carry out mass surveillance, rule on court cases or predict whether individuals will commit crimes.

New legislation that would introduce strict controls on AI to prevent racial, gender or age bias in particular "high risk" areas such as law enforcement is currently working its way through the European Parliament. But a report by its Committee on Civil Liberties, Justice and Home Affairs recently proposed even tighter controls, and a ban on AI's use in criminal justice and law enforcement. Last week, members of the European Parliament (MEPs) approved the report by 377 votes to 248.

Although there is no guarantee that this result will influence the draft AI legislation, a spokesperson for the parliament told *New Scientist* that such votes are "an opportunity to show which positions can command majorities in parliament, with a view towards future legislation".

"MEPs have made clear that police and criminal justice authorities in Europe must no longer be allowed to use AI systems which automate injustice, undermine fundamental rights and result in discriminatory outcomes," says Griff Ferris at campaign group Fair Trials.

The vote places the EU on a diverging course from the UK post-Brexit, as the country has played host to a number of AI trials that would probably be banned under the new EU legislation. For example, the Durham Constabulary police force has used an algorithm for several years to analyse a range of data, including a person's age, gender and offending history, to determine their likelihood for recidivism.

DAVID MCNEW/AFP VIA GETTY IMAGES

In London, the Metropolitan Police uses face-recognition technology to combat a range of crimes. The South Wales Police does too, although the force was required to change how it is deployed after a court ruling that previous trials were unlawful.

"Advancements such as facial recognition will help us tackle serious offences, including knife crime, rape, child sexual exploitation and terrorism. So it is right that we back and empower the police to use these in a way that maintains public trust," a UK Home Office spokesperson told *New Scientist*. The Ministry of Justice declined to comment.

> **"Police in Europe must no longer be allowed to use AI systems which automate injustice"**

The UK Office for Artificial Intelligence, which oversees possible regulation, is run by the Department for Digital, Culture, Media & Sport and the Department for Business, Energy & Industrial Strategy. Neither department responded to a request for comment.

A project involving the Alan Turing Institute and the UK government aims to build an ethical framework for the use of AI in the criminal justice system, but is still ongoing. The institute didn't respond to a request for comment.

Police forces are trialling the use of face-recognition tech

Sandra Wachter at the University of Oxford says the EU's careful approach is the way to go and that although the UK has lagged behind on AI regulation, it can catch up. "I absolutely don't think it's too late," she says. "I see a lot of institutions in the UK actually being very vocal around this, so I think there's still room to pivot in the right direction."

Current methods of AI-based policing are based on "inherently bad" data that probably isn't fixable because it was collected using unfair policing strategies, says Wachter. Measures are also needed to ensure they don't unfairly affect minority groups, she says. As an example, she points out that you are nine times more likely to be stopped and searched by police in England and Wales if you are Black. "Algorithm decision-making is only acceptable if the way we used to make decisions as humans is something that we're happy with," she says. ■

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[1] Source: Global Cement and Concrete Association

[2] Annual global cement production in 2019: 4.1 billion tonnes. Source: IEA.

[3] Precast industry is 30% of total. Sources: The Business Research Company & Fortune Business Insights.

[4] Typical passenger vehicle emits around 4.6 metric tonnes of CO_2 per year. Source: EPA.

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[1] IEA (2017), The Future of Trucks, IEA, Paris

[2] IEA (2020) CO_2 emissions from heavy-duty vehicles in the Sustainable Development Scenario, 2000–2030

[3] One young tree absorbs 5.9kg CO_2 per year. Source: Urban Forestry Network.

SHUTTERSTOCK/XKUNCLOVA

Animal behaviour

Some dogs have language abilities of a young child

DOGS with a special ability to grasp human language beyond simple commands can learn as many as 12 words a week, and can usually recall them after a two-month lapse.

So far, researchers have identified about a dozen pet dogs across the globe that possess the rare gift of word learning. These dogs associate objects with words and can have a vocabulary exceeding 100 terms.

In the latest study, scientists have discovered such pets can acquire words at a rate similar to that of a 1-year-old baby, says Shany Dror at Eötvös Loránd University, Hungary.

Dror and her team examined the abilities of six dogs that can do this. All were border collies, three males and three females. The researchers sent each dog's owner a box of six new toys. Owners then had six days to teach their dogs the names of the toys. At the end of this period, the researchers tested the dogs' abilities to pick out each toy by name from a scattering of old and new toys on the floor. All the dogs successfully brought back at least five of the six new toys.

The team then sent a second box with 12 new toys and repeated the process. All the dogs successfully brought back at least 11 of the toys.

Afterwards, half of the new toys were stored for a month and the rest for two months, then the dogs were retested. Five of the dogs remembered all the toy names after a month, and four remembered all or almost all after two months (*Royal Society Open Science*, doi.org/gzqv). **Christa Lesté-Lasserre**

Our Oldest Companions: The story of the first dogs is reviewed on p34

Solar system

Moon spewed lava relatively recently

THE moon may have been volcanically active for longer than we thought. Lunar samples brought back by the Chang'e 5 spacecraft include magmatic rocks less than 2 billion years old, indicating the history of the moon is more complex than we realised.

Researchers analysed two small samples returned from the region where China's mission touched down – known as Oceanus Procellarum – and found that they solidified from lava 1.96 billion years ago. This was long after many models of the moon's evolution suggested its volcanic activity should have ended (*Science*, DOI: 10.1126/science.abl7957).

These samples also had slightly different compositions than other moon rocks we have analysed, with more iron and less magnesium. "This indicates that the lunar interior is more complex and heterogeneous than we have anticipated," says Alexander Nemchin at Curtin University in Australia, part of the team.

One possible explanation for the late volcanism is that radioactive elements inside the moon kept it hot for far longer than we expected. "However, the chemistry of the fragments we have analysed does not match this idea very well," says Nemchin.

The other potential solution is the idea that when the moon was closer to Earth billions of years ago, the gravity of our planet could have heated its interior. "Much as the moon influences our tides on Earth, our planet could influence the mantle and deeper areas on the moon," says Katherine Joy at the University of Manchester, UK, who was also part of the research team. "The moon could have stretched and flexed back and forth, and that could have caused some melting." Other teams working on Chang'e 5 samples may shed more light on the true explanation. **Leah Crane**

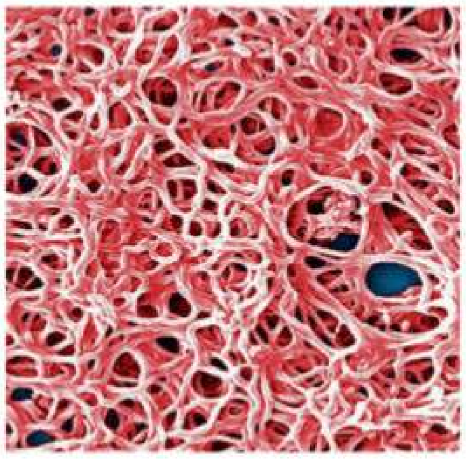
Antibiotics

Chemical could make Lyme disease history

THE discovery that a compound is deadly to the bacterium that causes Lyme disease but harmless to animals might allow the disease to be eradicated in the wild.

Lyme disease is caused by *Borrelia burgdorferi*, a bacterium in wild mice. Ticks that feed on the mice get infected and can infect other animals, including people.

The disease is a burgeoning problem in North America, Europe and Asia. It initially causes a characteristic "bullseye" rash and a flu-like illness. If untreated, it can lead to serious long-term health problems, such as Lyme arthritis.



RGB VENTURES/ALAMY

At present, it is treated with antibiotics such as doxycycline that kill a wide range of bacteria. However, this disrupts the gut microbiome, which is undesirable.

Now, Kim Lewis at Northeastern University in Boston and his team have found the compound hygromycin A is fine for animals and most bacteria, but is deadly to *B. burgdorferi* (pictured).

In animal tests, the team didn't observe any harmful effects of hygromycin A no matter how high the dose (*Cell*, doi.org/gzkt). "It is unusually safe," says Lewis.

A company called FlightPath is now filing in the US for the initial go-ahead required before the chemical can be tested in people.

In theory, dropping baits laced with hygromycin A could eradicate Lyme disease from whole areas or even countries. **Michael Le Page**

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Really brief

OLEG BRESLAVTSEV/GETTY IMAGES

Massaging muscle might boost repair

Massaging injured muscles may boost healing, a study in mice suggests. Injured mice that were massaged healed faster than those that weren't. Samples from the injury site hint massage clears immune cells that interfere with tissue repair (*Science Translational Medicine*, DOI: 10.1126/scitranslmed.abe8868).

Rivers on Mars carried huge rocks

An ancient lake that once sat in Jezero crater on Mars flooded billions of years ago, transporting boulders up to 1.5 metres wide. The rocks were photographed by NASA's Perseverance rover. The floods also deposited mud that might contain signs of life (*Science*, DOI: 10.1126/science.abl4051).

Ancient tardigrade preserved in amber

Microscopic tardigrades are the only animals known to have survived the vacuum of space – but they don't fossilise well. A specimen discovered in 16-million-year-old amber from the Dominican Republic is just the third example of a tardigrade fossil ever found (*Proceedings of the Royal Society B*, doi.org/gzqk).

Wildlife

Why city life trumps rural living for bees

A STUDY of the waggle dances of honeybees shows that those in central London don't have to fly as far to find food as bees in farmland outside the city.

"We knew that big cities were good for bees, but our study is contributing to showing why," says Elli Leadbeater at Royal Holloway, University of London. "There is more forage available."

In the summer of 2017, Leadbeater and her colleague Ash Samuelson visited 20 hives every two weeks to record waggle dances. The hives had glass panels, allowing the dances to be filmed without disturbing the bees. Ten of the hives were in farmland around London and 10 were in the centre of the city.

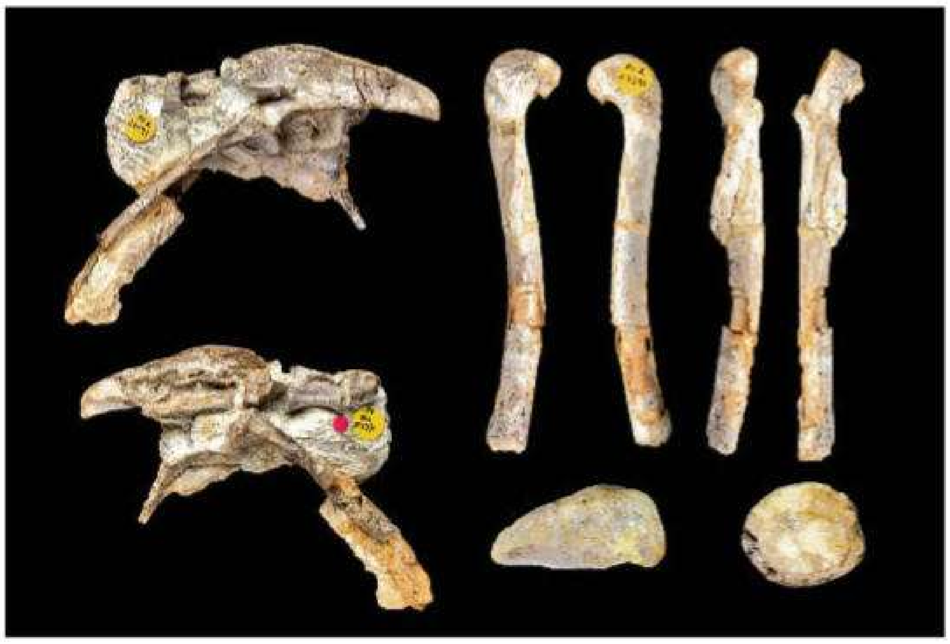
The waggle dances of the bees reveal the direction and rough distance of the best nectar sources found by foraging workers. Overall, Leadbeater, Samuelson and their colleague Roger Schürch at Virginia Tech decoded nearly 3000 waggle dances.

This showed that the median distance to sources of nectar was around 490 metres for city colonies, but 740 metres for those in farmland (*Journal of Applied Ecology*, doi.org/gzrd).

The findings suggest that the availability of food, rather than less pesticides or diseases, is the key reason why honeybees do better in cities than farmland, says Leadbeater. Parks and gardens provide more diverse, plentiful and reliable resources than farms.

Gardeners usually aim to have flowers throughout spring and summer, and water plants during dry periods, says Leadbeater. **MLP**

Palaeontology



SPIEKMAN ET AL.

Chief of the dinosaurs was once a chicken-sized predator

FOSSILS of a small meat-eating dinosaur discovered in a quarry near Cardiff offer the earliest evidence in the UK of theropods, a very diverse group of dinosaurs that includes *T. rex*, *Velociraptor* and all birds.

This animal, named *Pendraig milnerae*, lived between 200 and 215 million years ago in the Late Triassic Epoch. It was unearthed in a quarry called Pant-y-ffynnon north-west of Cardiff in the 1950s, but the fossil was lost for decades in the collections at the Natural History Museum in London.

When *P. milnerae* was alive, the region surrounding Cardiff was probably made up of a series of small tropical islands. It would probably have been one of the main predators on its island, which is why Stephan Spiekman at the Natural History Museum and his colleagues thought the name *Pendraig* – meaning "chief dragon" in 14th century Welsh – was suitable.

The species name *milnerae* was chosen to honour Angela Milner, a late palaeontologist who worked at the Natural History Museum for more than 30 years and who rediscovered the specimen in a drawer containing crocodile rather than dinosaur material (*Royal Society Open Science*, doi.org/gzqx). Krista Charles

Technology

Robot can walk, fly and skateboard

A TWO-LEGGED robot inspired by birds can walk, skateboard, fly and negotiate a slackline, which is like a loose tightrope. It has the potential to become a new tool to monitor infrastructure in hard-to-reach environments.

The robot, named LEONARDO by its creators at the California Institute of Technology (Caltech) and Northeastern University in Boston, is a human-like machine with knee, hip and ankle joints, but rotor blades for arms that give it upward thrust.

LEONARDO is 75 centimetres tall, weighs 2.6 kilograms and walks at up to 20cm per second (*Science Robotics*, DOI: 10.1126/scirobotics.abf8136). It is "the first robot to achieve seamless integration of walking and flying without human intervention", says Soon-Jo Chung at Caltech, one of the research team.

"Walking robots can struggle with uneven terrain, wheeled robots don't like debris, flying robots are normally stationary on the ground," says Jonathan Aitken at the University of Sheffield, UK. "The ability to mix these locomotion techniques makes the development of this robot a curious and exciting prospect." **Chris Stokel-Walker**

New Scientist
Events

ONLINE EVENT

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Comment

The disgust divide

Psychology is split on what exactly disgust is, but the evidence is starting to come in, says **Ana Aznar**

ROBERTO CIGNA

WE SHOULD really care about disgust. Not only does it protect us from coming into contact with possibly dangerous substances, such as rotting meat, but it is also central to understanding our moral compasses.

Yet, up until around 20 years ago, it was essentially absent from psychological research. Today, it is still shrouded in confusion. All other basic emotions, such as sadness and happiness, have a clear definition, but when it comes to disgust, psychologists are divided over whether it should actually be split into physical disgust and moral disgust, or whether it is only physical disgust that exists.

Physical disgust is that feeling caused by things such as vomit or faeces. This varies between people, but it helps protect us from touching or ingesting potentially dangerous substances that could put our survival at risk.

Moral disgust, on the other hand, is normally described as the feeling you get when hearing someone has broken social norms or moral codes. Seeing a person steal or hearing about someone having an affair, for example, might be enough to set off this emotion in you.

Some psychologists argue that physical and moral disgust are two sides of the same coin. Others insist that, although the word "disgust" is used in both situations, when moral norms are broken, what people are actually experiencing is anger.

Disgust and anger are both negative emotions that have been linked with morality, but whereas disgust motivates us to avoid things, anger pushes us to confront whatever it is that is making us angry.

In my latest research, I have been examining the schism in psychology on disgust further using parent-child conversations. These are a valuable tool for developmental psychology as parents use them to teach their children about emotions, values and moral issues. They may also be particularly relevant to our understanding of disgust because children only begin to understand it when they are 3 to 4 years old, around a year later than the other basic emotions. This suggests there is a social component to disgust and that children's understanding of it may be partly learned from their parents.

In the research, my colleagues and I asked 68 English-speaking mothers and their 4, 6 or 8-year-old children to discuss a series of short stories. In each of them, the main character performed either a physical transgression, such as wearing dirty clothes or sitting on a dirty chair, or a moral one, such as copying someone's homework or jumping a queue. We then asked the mothers and children to talk about the emotion that they would feel after each transgression.

We found that both were more likely to say that they were disgusted by physical transgressions than they were angry. In contrast, when discussing moral transgressions, they were more likely to say that they made them angry rather than disgusted. Mothers and children also often said that these actions were wrong.

What this seems to suggest is that mothers and children are more likely to link disgust with physical transgressions and anger with moral ones.

Does this mean there is no such thing as moral disgust? We think it certainly points that way.

Our research won't settle the controversy around the existence of moral disgust on its own. However, the more we learn about it, the closer we get to understanding how we develop a sense of morality. ▮

Ana Aznar is a psychologist at the University of Winchester, UK

Field notes from space-time

Staring at the stars The Hubble Space Telescope's journey to the sky was a bumpy one, but it was well worth the effort, writes **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an assistant professor of physics and astronomy and a core faculty member in women's studies at the University of New Hampshire. Her research in theoretical physics focuses on cosmology, neutron stars and particles beyond the standard model

Chanda's week

What I'm reading

Kyla Schuller's The Trouble With White Women: A counterhistory of feminism. *It is a call for a more inclusive feminism.*

What I'm watching

Jugando con Fuego, *Netflix's Spanish-language take on reality show* Too Hot to Handle.

What I'm working on

A paper that explains how to do a dark matter calculation by hand.

This column appears monthly. Up next week: Graham Lawton

FOR a brief, horrifying period this year, the Hubble Space Telescope wasn't working, and it wasn't clear whether it would ever get going again. Something was wrong with the electronics and even switching to the backup system didn't work correctly. This was a deeply emotional time for me and many other members of the astronomy community.

In my case, the death of this orbiting instrument is one of my worst scientific nightmares. When I saw the film *Gravity* recently, I wept at the scene that depicts Hubble being obliterated by high-speed space debris. I will always classify it as a horror film, not because of what Sandra Bullock's character endures as she tries to survive the terror of a catastrophic accident in space (which, yes, is pretty rough), but because Hubble's demise would seem like the end of the world as I know it.

Hubble's pristine images of deep space have become so culturally ubiquitous that people recognise them without knowing where they come from. An example is Jeff Hester and Paul Scowen's 1995 images of the "Pillars of Creation" in the Eagle Nebula, a star-forming region. The pictures aren't just beautiful, they also enhanced our understanding of how stars form.

However, Hubble's success wasn't always guaranteed. Nancy Roman, NASA's first chief of astronomy, is often recognised as the "Mother of Hubble," advocating for it when there were threats to cancel the overrunning and expensive mission. It took decades and cost billions, but the telescope ultimately launched in 1990, when I was just 7 years old.

Before it had the chance to revolutionise the way we see our universe, Hubble was the subject of high drama in space. It was launched manually by astronauts who piloted it into low Earth orbit on a space shuttle, part of a fleet of craft that is now retired, meaning future instruments are likely to be automatically deployed.

The space shuttle ended up being essential to Hubble's success though, not just because of the launch, but because initially the instrument suffered from a mirror defect that significantly decreased the quality of its images. In 1993, astronauts flew the space shuttle Endeavour to Hubble and in a series of spacewalks over days, repaired the telescope. It was updated in a similar fashion three more times. The last was in 2009, just before the space shuttle was taken out of operation.

> **"I classify *Gravity* as a horror film because the end of Hubble would seem like the end of the world as I know it"**

Today, if there is a problem with Hubble, it has to be resolved from the ground, and this is ultimately what happened over the summer, successfully this time. There will be no more physical repairs. I regularly feel anxious about this, as I have spent the majority of my life seeing the universe through Hubble's optical, infrared and ultraviolet eyes, and my career as a particle cosmologist has been completely shaped by its results.

Today, the Nancy Grace Roman Space Telescope (NGRST) is in the works and will hopefully join Hubble in the sky before this decade is over. NGRST will pursue the cosmic acceleration mystery that was uncovered in the late 1990s using Hubble data.

Along with dark matter, cosmic acceleration is perhaps the greatest open question in cosmology: not only is space-time expanding, but that expansion is also occurring at a rate that is increasing with time, and we don't know why. I wrote my PhD dissertation on possible explanations for this, and the new telescope promises to provide additional data to help us choose between models.

As regular readers know, I have gone on to become very focused on dark matter, the other great cosmological problem of our time, and Hubble has had plenty to say about this too.

One observational phenomenon that Hubble has been particularly effective at capturing is something called gravitational lensing, where the presence of dark matter distorts space-time so much that light arriving from a galaxy or star takes a noticeably curved trajectory. Sometimes the lensing is so strong that it causes multiple images of one object to appear on a telescope's detectors. It is a bit like dark matter causing space-time to behave like a funhouse mirror.

Using knowledge of Einstein's general relativity in combination with observations of lensed objects allows us to characterise basic properties of the clumps of dark matter that caused the distortions in the first place.

Just last year, a team led by Daniel Gilman at the University of California, Los Angeles, used this kind of observation to place bounds on the dark matter parameters that characterise the evolution of galaxies and the dark matter halo that we believe surrounds each galaxy.

Hubble has affirmed for us that there is still so much about the universe that we don't know, even as it continues to help us increase our understanding of it. ▮

FREE EVENT

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Debate

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CAN BRITAIN BECOME A NEW SPACE PIONEER?

Thursday 18 November 2021
6-7pm GMT, 1-2pm EST and on-demand

Next year, UK spaceports will become capable of hosting space launches from the UK for the first time. The development is part of an ambitious plan to make the UK a meaningful actor in space, both in military and civilian spheres, and to allow British industry to exploit new space-related technologies for smaller, cheaper and more effective satellites. To make this happen, the government recently set out its National Space Strategy and created the UK Space Command to defend British interests and guarantee secure communications in space; it also introduced the legal framework necessary to allow launches from British soil. But is Britain ready for the challenge?

This *New Scientist* debate will ask whether Britain has the expertise and industrial base to meet these ambitions and explore how it can best exploit these foundations in an increasingly competitive global market for space.

Panellists

Air Vice-Marshal Paul Godfrey
Commander of the
UK Space Command

Emily Gravestock
Head of Applications Strategy,
UK Space Agency

Dave Short
Technology Director,
BAE Systems

Justin Mullins
Consultant editor, *New Scientist*
and debate chair

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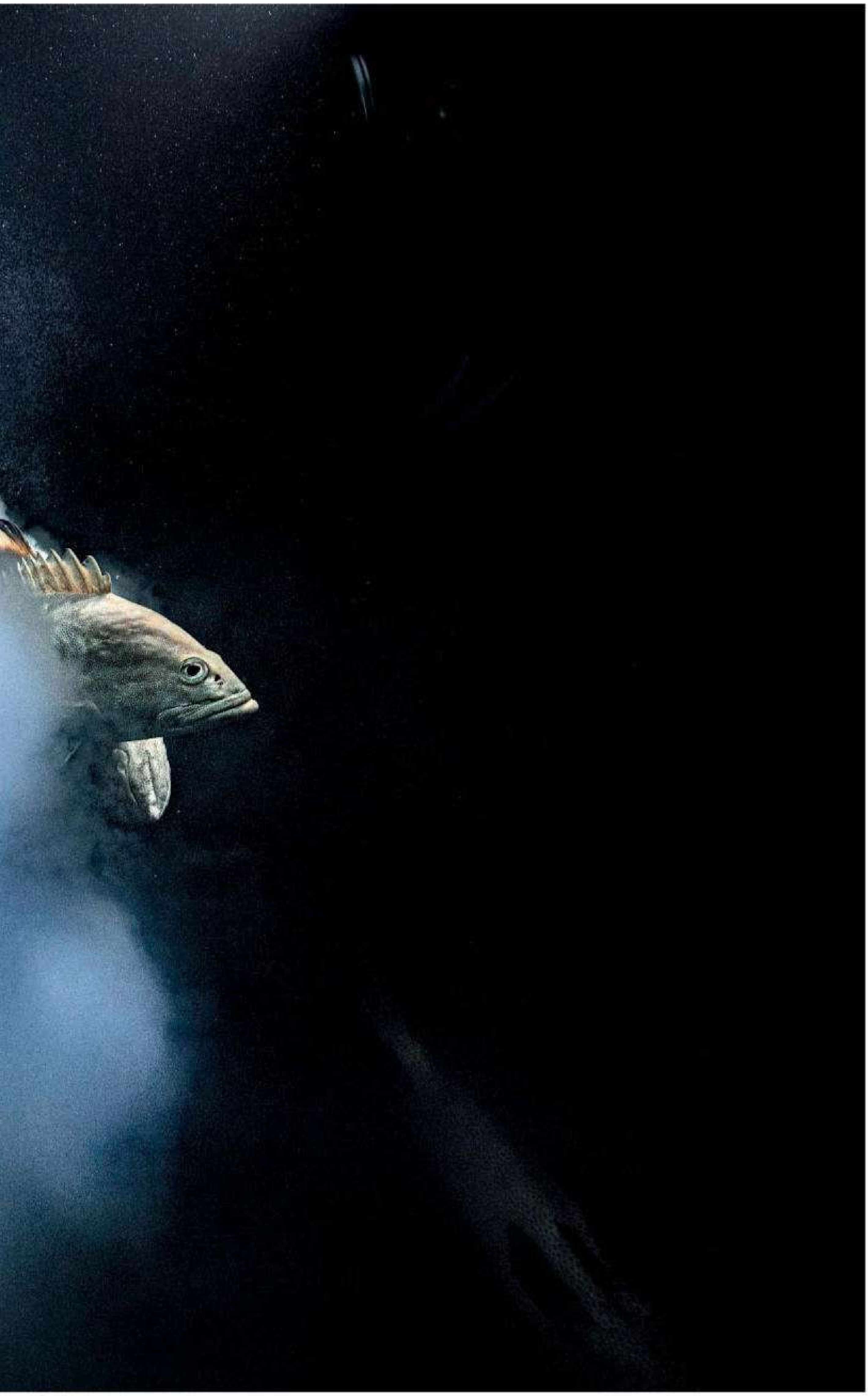

LEFT: LAURENT BALLESTA / WILDLIFE PHOTOGRAPHER OF THE YEAR RIGHT: VIDYUN R HEBBAR / WILDLIFE PHOTOGRAPHY OF THE YEAR

Group(er) photo

Wildlife Photographer of the Year competition

THIS remarkable underwater shot of a cluster of camouflage groupers (*Epinephelus polyphekadion*) in Fakarava, French Polynesia, has won photographer and biologist Laurent Ballesta the 2021 Wildlife Photographer of the Year competition, organised by the Natural History Museum in London.

Titled *Creation*, the image captures a moment in the groupers' annual reproductive season, which is synchronised with the moon. Clouds of eggs and sperm are released into the water when the fish spawn around the time of a full moon.

Camouflage groupers (also known as blue-tailed cod, among other names) are usually spread out around the shallow coral reefs in which they live, but can assemble in their thousands during spawning. However, overfishing is shrinking the size of these aggregations.

The smaller image below, titled *Dome Home*, shows a tent spider amid the backdrop of a tuk-tuk, a type of motorised rickshaw. It was taken by Vidyun R. Hebbar, who was awarded Young Wildlife Photographer of the Year for the image.

The competition's winning and shortlisted entries across the many different categories will be exhibited at the Natural History Museum from 15 October.

Gege Li

Editor's pick

Bin tax? Just look to the world's cleanest country

25 September, p 18

From Valerie Hungerford, Bettingen, Switzerland

You report on the idea of making households pay for the rubbish they throw away, as a means to decrease pressure on landfill and increase recycling, without much hope of any such scheme being implemented in the near future in the UK.

Switzerland has had this for decades, based not on weight, but on volume. "Burnable" rubbish must be put in a special bag, obtainable from supermarkets. The bags come in various sizes, with the price set to cover disposal – not so high as to encourage fly-tipping, but even a modest sum nudges everyone to minimise the waste they generate. Commercial premises pay a higher fee for a whole container's worth.

Putting glass, paper, plastics, aluminium, tin cans, batteries and so on into the various recycling bins is free. Electrical waste can be taken back to any shop selling electrical goods, with the cost of recycling covered by a prepayment included in the price of goods.

Food waste: try pigswill and spreadsheets please

25 September, p 42

From David Byrne, Swinton, Scottish Borders, UK

Marta Zaraska made important points about food waste, especially from restaurants and other food outlets. One factor in this are the UK and EU bans on the use of this waste as pigswill. Pigs, and chickens and rabbits during the second world war in the UK, have always been used to convert food waste into protein.

Pigswill was banned after the 2001 outbreak of foot-and-mouth disease in the UK, but Japan and South Korea still use it and control the disease well. We will have to once again move to using our waste to feed animals.

From Paul O'Neill, Thornton-Cleveleys, Lancashire, UK

For the past two years, I have been putting all my food purchases onto a spreadsheet, detailing the quantity and use-by or best-before dates. Since I began, I have only wasted two items. I review the list daily and make my menu for the following day from it.

There are many ways of looking at military AI

2 October, p 14

From Tim Stevenson, Prestwood, Buckinghamshire, UK

Some will say that using AI to identify targets for military strikes is a dangerous step down the road to mechanised, dehumanised warfare. Others will say that having two parallel decision processes, AI and human, will reduce, though not eliminate, error. Yet others will say that no targeting can be perfect, so no strikes should ever take place.

The only sensible criterion is the utilitarian one, always recognising that value judgements must be made. Preventing or reducing a great evil at the risk of a smaller one can be a least-worst course.

From Richard Prior, Beaworthy, Devon, UK

Questions about such use of AI are raised by Arthur Holland at the UN Institute for Disarmament Research. He asks whether, in the case of an erroneous target selection, the use of AI might "affect the balance of human responsibility and accountability". I find this troubling because the question itself suggests we are yet again in danger of allowing people to "blame the computer".

We cannot afford to allow anyone in the chain of command to hide behind the argument that they weren't responsible for the actions of their agents, regardless of whether the agents in question were human or machine.

Don't allow heat pumps to be used to cool homes

Letters, 2 October

From Fred White, Nottingham, UK

Ken Jensen's timely warning that heat pumps can operate on a cooling cycle in the summer should ring very loud alarm bells. Unless this feature is disabled by legislation, as the UK government seeks to roll out this type of system, it is just another way to accelerate the apocalypse as energy use will explode to meet "vital" cool comfort conditions.

Summer heat calls for better house design, with shade, planting, parasol and venting features.

Bitcoin as national legal tender is a terrible idea

18 September, p 16

From Sam Edge, Ringwood, Hampshire, UK

Yes, there is a need to maintain the ability to perform anonymous transactions in a free society. However, the news that the El Salvador government is accepting bitcoin – billed as anonymous – as tender is disturbing. Proof-of-work blockchain currencies like bitcoin are a bad idea because of their carbon footprint from the use of lots of energy and materials.

True spite is in the eye of the beholder

4 September, p 40

From Robert Howarth, Sheffield, UK

The experiments cited in your entertaining article on spite could cut two or more ways.

For example, in the Ultimatum Game, the potential spitefulness of the "receiver" is considered in a one-play, known-rules, sharing game, yet the possible spitefulness of the "giver" goes unremarked. Why is it spiteful to reject 20 per cent of a shared pot of money when both parties know this is about sharing an unearned gift, yet the spitefulness of the short-changing "giver" is ignored?

Moggies gurn when they want to play-fight too

2 October, p 23

From Caroline Peters, Winnersh, Berkshire, UK

You report that hyenas make a face when they want to play-fight. Cats also make play faces. Our 11-year-old arches her whiskers forward and opens her mouth slightly when playing. Her expression when hunting or fighting is very different – the play face can't be mistaken. I have had numerous cats over the years and they all had a distinctive play face.

Foundation eventually got its share of female heroes

2 October, p 32

From David Clarke, Seaford, East Sussex, UK

I have sympathy with the view that women don't feature significantly in the first book of Isaac Asimov's *Foundation* series. I would, however, point out that in subsequent parts of the trilogy, we do see three significant and strong women: Bayta Darell, Arkady Darell and Lady Callia. Perhaps Asimov was feeling guilty. ▮

For the record

- **Grace Maddrell, author of *Tomorrow Is Too Late*, uses they/them pronouns (2 October, p 33).**
- **A quote in our feature on AI (9 October, p 36) was partially attributed. It was made by Ellie Pavlick at Brown University in Rhode Island and Google AI.**

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MEDECINS SANS FRONTIERES
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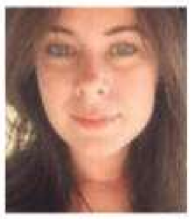
AFGHAN CRISIS APPEAL

"Fighting in Afghanistan had been intense since May, but in August the situation got progressively worse."



SARAH LEAHY
PROJECT COORDINATOR

"For a time, the frontlines ran right by our hospital in Lashkar Gah.

We were located in between strategic buildings and rockets would be going over the hospital, explosions occurring and bullets hitting the buildings all the time. We were exposed to the crossfire and twice we were hit by rockets.

It was very intense, but through all the fighting we carried on working. It's a huge hospital, one of MSF's biggest projects, and is an absolute lifeline in Helmand province. We have nearly 1,000 Afghan staff, an emergency room where we treat more than 500 patients a day and a maternity ward with an average of 60 deliveries a day.

During the fighting we were getting 30 to 40 people in for surgery each day with bullet wounds and injuries from shelling and explosions.

Many people who needed medical care struggled to reach us. People were forced to wait at home until the fighting subsided, while others were caught up in crossfire on their way to hospital. People would be coming to see us for pneumonia, then get caught up in the fighting and arrive with a bullet in the shoulder or the leg. Roads and bridges had been bombed, so what should have been a 40-minute journey to hospital took four hours. There was no fuel, but people were coming on foot from all over the province, on pushbikes with pregnant women, all in 48-degree heat.

The health system in Afghanistan has essentially collapsed. It wasn't in great shape in the first place, but now the situation is desperate. That's why it's so important that MSF is still there, conducting surgeries, helping women give birth, giving people the basic, lifesaving healthcare that they need. It's vital that Afghanistan and the people who need our help are not forgotten."

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The Afghan Crisis Appeal will fund MSF's work in Afghanistan, as well as supporting our work in neighbouring countries.

Above: An MSF team perform surgery in one of three operating theatres at Boost hospital, Lashkar Gah, Helmand province. *Photograph © Tom Casey*

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Friends with benefits

Dogs may be cute and cuddly now, but our special relationship had fierce and bloody origins, finds **Simon Ings**

Book

Our Oldest Companions: The story of the first dogs
Pat Shipman
Belknap Press

WHEN Spanish and other European forces entered South America in the 15th century, they used dogs as weapons to massacre the indigenous human population. Sometimes, their mastiffs, enormous brutes trained to chase and kill, even fed on the bodies of their victims.

This didn't quell the affection in South America for dogs, though. Ferocious as they were, these beasts were also novel, loyal and intelligent and a trade in them spread across the continent.

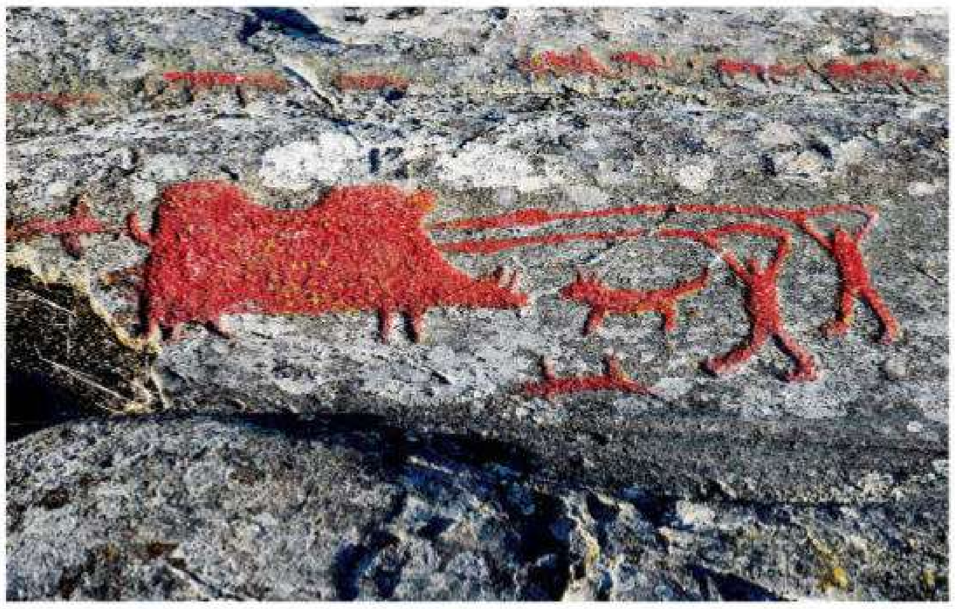
What is it about dogs that makes them so irresistible?

In *Our Oldest Companions*, anthropologist Pat Shipman traces the ancient drivers that led to our species' special relationship with dogs. It is an epic, and occasionally unnerving, tale of love and loyalty, hunting and killing, gleaned from a huge amount of archaeological and palaeogenetic research.

In Shipman's view, there was nothing inevitable about the development of the grey wolf – a fierce, meat-eating competitor – into the playful friends that we know today. As Shipman puts it: "Who would select such a ferocious and formidable predator as a wolf for an ally and companion?"

To find the answer, says Shipman, forget the old tale in which someone captures a baby animal, tames it, raises it, selects a mate for it and brings up the friendliest babies.

Instead, she argues, it was the particular ecology of Europe about 50,000 years ago that drove grey wolves and human interlopers from Mesopotamia to develop a symbiotic relationship that set the stage for our future friendship.


ROLAND MAGNUSSON/ALAMY

The speed of dogs and our weapons proved a deadly combination

"Who would select such a ferocious and formidable predator as a wolf for an ally and companion?"

Cute, but there was never a good enough reason to team up with dingoes

JULIE FLETCHER/GETTY IMAGES

Working together allowed humans to tap into the wolves' superior speed and senses, and to gain their protection against other large predators including lions. The wolves, in turn, benefited from a human's ability to kill prey at a distance with spears or arrows.

It was a partnership that allowed them to net enough food to share, and to outcompete the indigenous Neanderthals who didn't have a team of super-fast predators to help them.

This idea was explored in Shipman's 2015 book *The Invaders*. *In Our Oldest Companions*, she develops her argument by exploring parts of the world where dogs and humans didn't evolve similar behaviours.

Australia provides Shipman with her most striking example. When *Homo sapiens* arrived in Australia, around 65,000 years ago, they came without domesticated dogs, because, at the time, there was no such thing.

When the ancestors of today's dingoes were brought to Australia about 3000 years ago, their charisma earned them a central place in Indigenous Australian folklore, but there was no incentive for the two species to live and work together. Australia was less densely populated by large animals than Europe and there were only two large mammalian predators, the Tasmanian tiger and the marsupial lion, to deal with. As a result, says Shipman, while dingoes are eminently tameable, they have never been domesticated.

With the story of humans and dogs in Asia, Shipman goes against the grain. While some researchers argue that the bond between wolf and man was first established here, Shipman is having none of it. She points to a crucial piece of non-evidence: if dogs first arose in Asia, then where are the ancient dog burials?

"Deliberate burial," writes Shipman, "is just about the gold standard in terms of evidence that an animal was domesticated." There are no such ancient graves in Asia, she points out. It is on the right bank of the Rhine in what is now Germany, that the earliest remains of a clearly domesticated dog were discovered. Known as the Bonn-Oberkassel dog, and dating from 14,200 years ago, it was found in 1914, tucked between two human skeletons, the grave decorated with works of art made of bones and antlers.

From there, domesticated dogs remained firmly in our hearts and homes. There are now more than 300 subspecies, although overbreeding has left hardly any that are capable of carrying out their intended functions of hunting, guarding or herding.

Shipman passes no comment on this, but I can't help but think it is a sad end to a story that began among mammoths and lions. ▮

Animal lockdown

Zoos play an important role in conservation, but let's not pretend they have no problems, says **Elle Hunt**

Film

Escape from Extinction

Matthew R. Brady

In selected UK cinemas now

LIKE so many nature documentaries these days, *Escape from Extinction* begins with the bad news: a parade of global headlines trumpeting the dire toll of drought, deforestation, oil spills and extreme weather on life on Earth. This particular film, directed by Matthew R. Brady, then focuses on species threatened by the human-induced sixth mass extinction event.

Escape from Extinction soon breaks ranks from other environmental documentaries, because of its unique take on the best way forward: zoos and aquariums.

Actor Helen Mirren's narration assures us that zoos have changed. "Once synonymous with exhibition and entertainment, modern zoological facilities are leaders in the fight against mass extinction," she says.

This position is made clear in the opening titles, which identify American Humane – a non-profit organisation that runs a certification programme for the welfare of animals in human care – as producer. The documentary is essentially an adaptation of the white paper published by American Humane in support of its Humane Certification programme, arguing that zoos are "modern day arks".

Even if that connection passes you by, it is impossible to miss the cheerleading for zoos throughout. "The only reason certain species are alive today is because zoos and aquariums have saved them from extinction," says American Humane president Robin Ganzert. They are even championed in areas where their potential for impact is limited, such as ocean plastic pollution. Mirren praises the "entire exhibits now dedicated" to the issue, but it's not clear how they will actually help.

It is certainly true that zoos make significant contributions to conservation, not least in maintaining insurance populations of species that are at risk of being lost from the wild. Certification for responsible zoos is presented as a solution to mounting ethical objections to animals being kept in captivity. But the nuances of the moral equation are lost in the film's rush to posit zoos as the answer. Meanwhile, legitimate criticisms, such as the cruelty of keeping cetaceans in aquariums to perform for audiences, are presented as the emotive and uncritical thinking of animal rights "extremists" (Ganzert's word).

Some of the arguments put forward in *Escape from Extinction* are little more than straw men, such as that the word "captivity" carries an unfair stigma that wouldn't apply to your pet dog – as though that is a neat parallel with an orca.

The repeated reference to "zoological facilities" in Mirren's narration comes across as an attempt to make zoos sound like the rational, scientific option.

The one thing the documentary does do well is to make the problem of extinction feel urgent. There are galvanising stories of critically endangered species, such as the pangolin, and hopeful tales of those that have been brought back from the brink, like the New Zealand kakapo.

It also rightly calls for action over sentimentality. "Repairing the damage we've done to the environment requires more than abstract inspiration," chides Mirren.

For me, though, the film falls down with its central message: that the imminent ecological collapse is evidence of the urgent need for zoos. It is disingenuous to claim awareness-raising and captive breeding programmes as the answers to mass extinction when, at this late stage in the crisis, what is needed is a radical restructuring of the economy, habitat protection and restoration, and the will to act now. Ultimately, though, *Escape from Extinction* is less concerned with rattling cages than it is with ensuring they hold strong. ▮

Elle Hunt is a writer based in London

KALEIDOSCOPE ENTERTAINMENT

Captive breeding is a lifeline for some species, but is far from our only weapon against extinction

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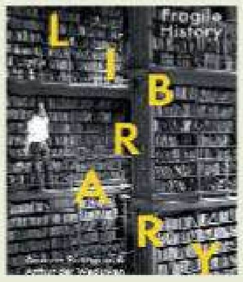

Read

The Library is Andrew Pettegree and Arthur der Weduwen's celebration of book collections, both aristocratic and public. The book explores the ancient origins, eventful history and vulnerability to destruction of libraries.

Watch

Dune
Timothée Chalamet plays Paul Atreides, the boy destined to rule the universe (if giant worms don't get him first) in Denis Villeneuve's *Dune*. In UK cinemas from 22 October. See newscientist.com for a full review.

Visit

Sonic Ray lights up London's lighthouse, where Michael Faraday did experiments in the 1840s. A 1000-year-long piece of music will be encoded into a laser and beamed across the Thames at the speed of light.

DUNE – WARNER BROS. ENTERTAINMENT INC; SONIC RAY: COURTESY OF ARTANGEL. PHOTOGRAPH: IBRAHIM SERRA-MOHAMMED AND ASCENSION FILMS

Science is fun, kids

Ada Twist is a perky young scientist who is bursting with curiosity. That may sound annoying, but her enthusiasm is infectious, says **Gregory Wakeman**

TV

Ada Twist, Scientist
Netflix

Available now

THE creatives behind *Ada Twist, Scientist*, a Netflix show based on Andrea Beaty and illustrator David Roberts's bestselling picture book series, always knew that their adaptation would have a lot to live up to. Thankfully, a brilliant team has been amassed to bring the animated show to life.

The company behind the six-episode first season is Higher Ground Productions, which just so happens to be run by former US president Barack Obama and former first lady Michelle Obama.

COURTESY OF NETFLIX

Ada will definitely subscribe to *New Scientist* in a few years

Each half-hour instalment of *Ada Twist, Scientist* was developed by Chris Nee, the brain behind the adored children's television series *Doc McStuffins*, *Ridley Jones* and *Vampirina*. The result is 12 short science lessons that everyone can learn from.

The show follows 8-year-old Ada, who is infatuated with science and figuring out how it makes the world work. Alongside her best friends Iggy Peck and Rosie Revere, as well as her mum, dad, older brother Arthur and mischievous cat Mooshu, Ada asks endless questions, goes on various fact-finding missions and creates elaborate scientific experiments.

While all of the above might tempt you to think that Ada is just a little annoying, that couldn't be further from the truth. Thanks to Amanda Christine's superb vocal efforts, Ada's curiosity is genuinely contagious. More than that, she injects an energy and enthusiasm into the show that will instantly engage younger viewers and provoke a smile from even the most jaded parents.

> "Ada will instantly engage younger viewers and provoke a smile from even the most jaded parents"

It is easy to see why the Obamas were so eager to bring Ada Twist's scientific shenanigans to a wider audience. When they signed their multi-year deal with Netflix, the pair said that their goal was to use the power of storytelling to inspire people to "think differently about the world around us, and to help us open our minds and hearts to others".

Ada Twist, Scientist does that from the opening lyrics of its catchy theme song. It asks viewers to always be curious and wonder "how, what, where, why", before reminding us that "science is everywhere you look".

For the show's opening episode, entitled "A Fort Of One's Own", this approach sees Ada using household items to create chain reactions that unlock the entrance to Arthur's garden fort. Throughout this journey, Ada drops various pearls of wisdom.

For example, when she, Iggy and Rosie become stuck, she remains upbeat and insists: "The only way to fail is to quit." Then, she galvanises her pals by reminding them that scientists are only able to resolve the unsolvable by answering numerous small questions first.

Each episode is made up of two of Ada's animated adventures, which are around 10 minutes long. These are followed by footage of real-life scientists introducing themselves and their professions in a way that makes the scientific elements of their work easy to understand. This includes aerospace engineer Keji Sojobi – who designed the chain reactions on the James Webb Space Telescope that allowed it to unfold in space – as well as desert botanist Naomi Fruja, solar engineer Sarah Kantor and biomedical engineer James Findlay.

Though *Ada Twist, Scientist* is aimed at children, many parents watching along will also find it informative, educational and a whole lot of fun. ▮

Gregory Wakeman is a film critic based in Philadelphia, Pennsylvania

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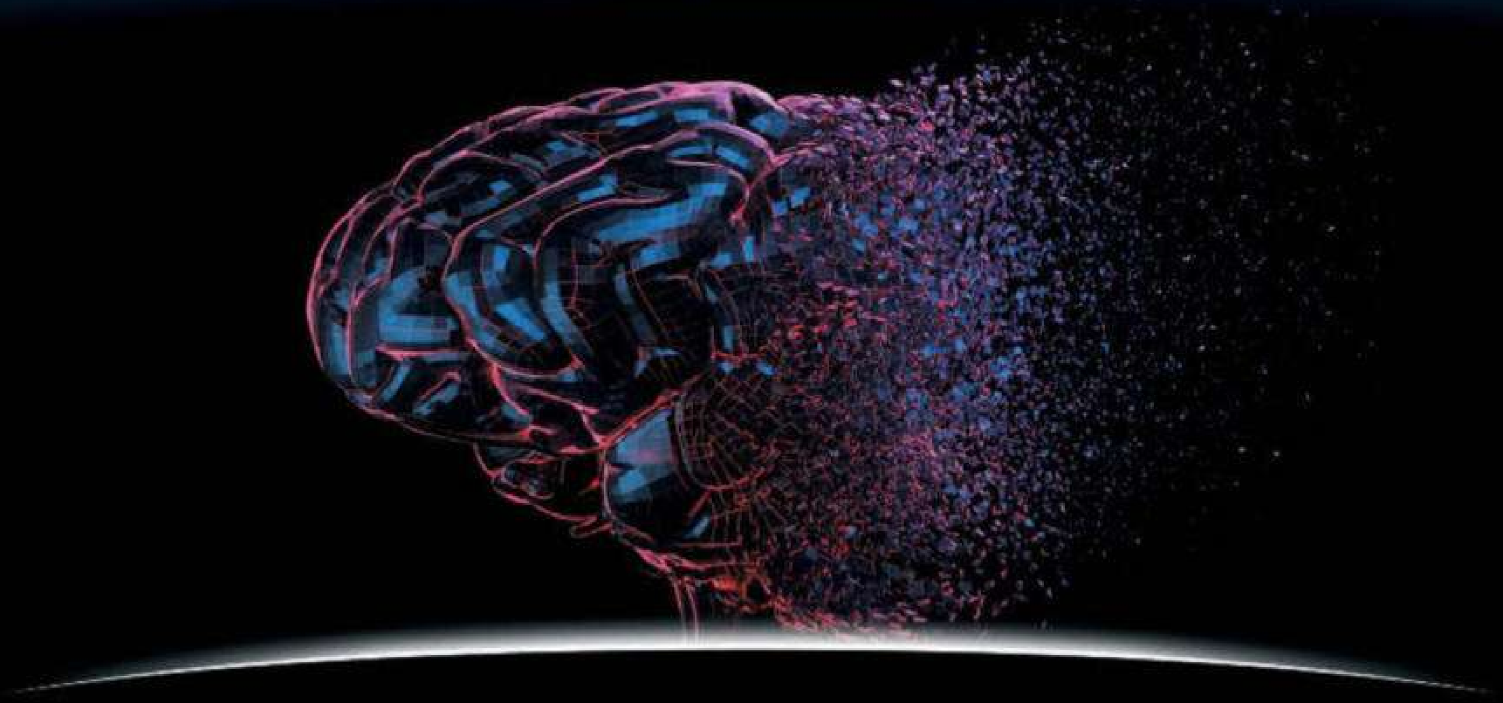

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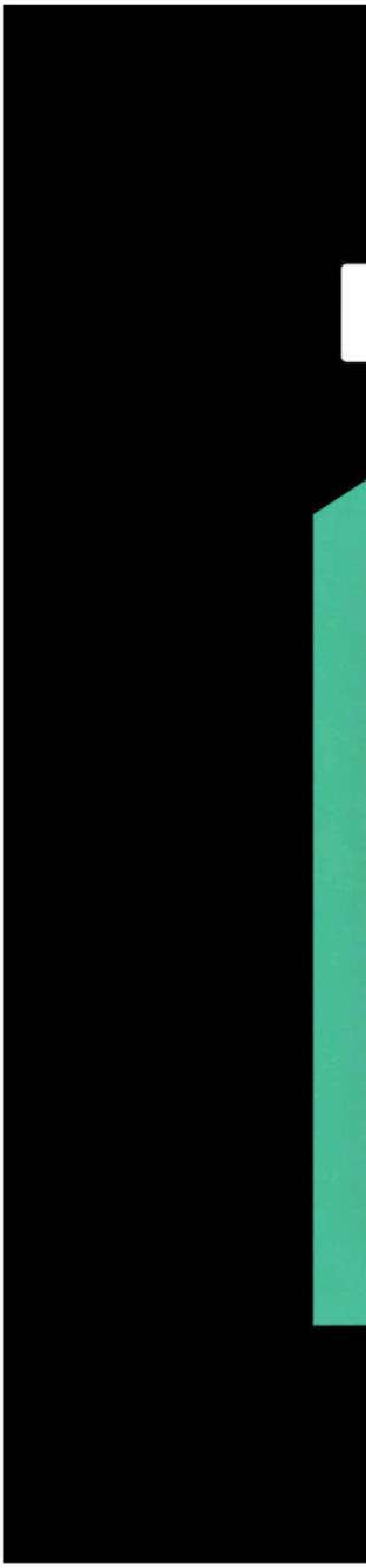
The future of medicine unlocked

When the covid-19 pandemic finally showcased the power of mRNA therapies, it opened the door to a medical revolution, finds **Michael Le Page**



GIULIO BONASERA

VIRUSES may be our enemies, but they have taught us a thing or two. When a virus takes hold, it hijacks our cells and puts them to work churning out the materials to make more virus. It is a diabolically effective strategy, allowing these invaders to rapidly grow their forces and get the jump on our immune systems.

The thing is, if they can commandeer our cells' protein-making factories for their own ends, why can't we do the same to bolster our defences? We can, it turns out. This was the insight that set in motion decades of research that culminated in the Pfizer/BioNTech and Moderna vaccines against covid-19: they use the genetic material messenger RNA to tell our cells to produce a protein that teaches our bodies to recognise the invaders.

The pandemic has been a proving ground for this technique, spectacularly demonstrating how rapid – and potentially cheap – it can be. "The covid vaccines really illustrate how quickly one can develop these medicines," says Pieter Cullis at the University of British Columbia in Canada. "From a standing start you saw things being in the clinic in three months."

Vaccines are only the beginning. If we can recruit our bodies to make medicines this way, that opens the door to treating everything from bacterial infections to autoimmune conditions, rare genetic disorders and cancer. "It is a revolution in terms of the medicines you can imagine, and also produce and test very quickly," says Cullis. It is early days yet, even if promising results are already coming in. And yet it is no exaggeration to say that this could change everything.

To grasp why there is so much excitement about the potential of mRNA vaccines and related treatments, we need to go back a bit. Early vaccines consisted of "live" viruses, typically with mutations that make them less dangerous than the wild virus they protect against. Live vaccines can be very effective, but have drawbacks: they are tricky to make, because viruses can only be produced by living cells, and they can be a threat to people with weakened immune systems. What's more, live vaccine viruses sometimes mutate back into a dangerous form, as happens occasionally with the live polio vaccine.

This is why many modern vaccines consist of "dead" or inactivated viruses, or even just one isolated protein from a virus, in the case of subunit vaccines. But these aren't any easier to make: any protein-based medicine still has to be produced in living cells.

This requirement is an issue at every stage of traditional vaccine development, from preparing doses for initial tests to mass manufacturing. It also makes it hard to tweak candidate vaccines if they don't work well.

But many decades ago, biologists realised there is a potential shortcut: instead of injecting the virus or its proteins, give our

bodies the genetic recipes for making viral proteins. Recipes for proteins are usually permanently stored in the DNA in the nucleus of our cells. When a cell needs to make a protein, it makes an RNA copy of the recipe, in the form of mRNA. These mRNAs deliver the instructions to the cell's protein-making machinery, until, after a few hours or days, they break down and protein production ceases.

A new recipe

Back in 1990, in experiments in mice, biologists demonstrated that it was possible to add either DNA or mRNA coding for a protein to living cells and get them to churn out that protein. What made this so exciting is that DNA and RNA are much easier to produce in the lab than proteins. It showed that, once you have the code you need for the mRNA to make a protein to prime the immune system for a given virus, you should be able to crank out a prototype vaccine remarkably quickly. "You are not relying on any biological processes during the manufacture, so it's a much more straightforward process," says Cullis.

But as often happens in biology, going from theory to practice was easier said than done. A big issue was that, because many viruses and parasites use forms of RNA to hijack cells, our bodies have lots of defences against it.

Our blood, sweat and tears contain enzymes called RNAses that rapidly chew up any RNA found outside cells. And if foreign RNA does get inside cells, it triggers an array of defences. "Your body has evolved to have all these mechanisms to sense RNA viruses," says Anna Blakney at the University of British Columbia.

Of course vaccines need to set off the immune system's alarm bells, summoning cells that target any foreign material they find. But the response to RNAs introduced into the body is so strong that they are destroyed before the desired protein can be made. For these reasons, most biologists thought mRNA vaccines were a non-starter and focused on developing DNA-based vaccines instead. But that has yet to lead to much: so far, trials of DNA vaccines have been disappointing, failing to provoke a strong immune response.

Then in 2005, came the first of two critical developments that transformed the prospects for RNA versions. That year Katalin Karikó and Drew Weissman at the University of Pennsylvania managed to chemically › modify mRNAs to dodge immune detection inside cells. With fewer added mRNAs being destroyed by cellular defences, protein production rose up to 1000-fold.

Perfect packaging

Secondly, other research groups had figured out ways of packaging RNAs in tiny oily balls called lipid nanoparticles that protect them from RNAses in the blood and get them into cells. This approach had to overcome a big challenge. RNA is negatively charged, so will only combine with positively charged lipids, but positively charged lipids are toxic, says Cullis, who helped develop the lipid nanoparticles used to package the Pfizer/BioNTech vaccine. "They tend to rip cells apart."

The clever solution was to develop lipids that are positively charged to begin with, allowing the RNA to be encapsulated, but lose this charge inside our bodies. This key technology has been gradually refined over many years. During the 2010s, human trials of a drug called patisiran, which uses another kind of RNA called small interfering RNA, or siRNA, showed that lipid nanoparticles are safe and paved the way for their use in mRNA vaccines.

Around the same time, the enormous promise of mRNA vaccines was starting to become clear. In March 2013, some 100 people in China became infected with H7N9 bird flu. When the genetic sequences of the virus were posted online, a team at pharmaceutical firm Novartis created a potential mRNA vaccine from scratch in just eight days.

Within weeks, the vaccine candidate was shown to produce a good response in mice. The work set an astounding new speed record – getting to this stage can take a year or more with conventional vaccines.

But the outbreak ended and this work wasn't taken further. Progress remained slow. Big pharma companies didn't see much profit in pursuing a new and unproven vaccine technology, and left it to smaller companies such as BioNTech and Moderna. "Everybody was sceptical about it," says Blakney.

When the pandemic began in 2020, there had been many small trials of mRNA vaccines, mostly designed to treat cancers by inducing

Injection of hope

After the triumph of mRNA vaccines for covid-19, investment in this technology has skyrocketed. Already this year, 71 mRNA vaccine trials have been announced or begun, says Jessica McCormack at analytics firm GlobalData, compared with just two in 2018. The vast majority are for infectious diseases.

The hope is that mRNA vaccines can do three things: provide better alternatives to existing vaccines, such as the BCG vaccine for tuberculosis; accelerate the development of vaccines against diseases for which there are none, from HIV to herpes; and allow us to respond to future pandemics even faster.

When it comes to improving on existing vaccines, flu is high on the list, says Anna Blakney at the University of British Columbia in Canada. Seasonal flu vaccines are just 30 to 40 per cent effective. "It's just dismal," she says.

Most flu vaccines are still made by growing the virus in eggs before modifying it for use as a vaccine, a long process. This means that, for the northern hemisphere, the flu strains to be included in a jab have to be chosen around February. By the time flu season hits in October, the circulating strains have changed a lot, says Blakney. "That's where RNA vaccines could make a big difference."

Another advantage of mRNA is its flexibility, says Norbert Pardi at the University of Pennsylvania. It should be possible to vaccinate against 10 or more diseases at once. Moderna, for instance, is working on a combined seasonal vaccine against a range of viruses, including respiratory syncytial virus (RSV), human metapneumovirus (hMPV), flu and SARS-CoV-2, which causes covid-19.

mRNA technology might also boost efforts to develop vaccines against several types of flu virus, including those in animals that could jump into people and cause a pandemic. "If you can develop a broadly protective or universal flu vaccine before the next pandemic, you don't need to worry about time," says Pardi.

There are also efforts to use the mRNA approach to develop a pan-coronavirus vaccine, better fend off malaria and finally create a vaccine against HIV. Both BioNTech and Moderna are working on HIV candidates, and Moderna started a clinical trial of one in August. "We have a good chance of coming up with an HIV vaccine," says Pardi.

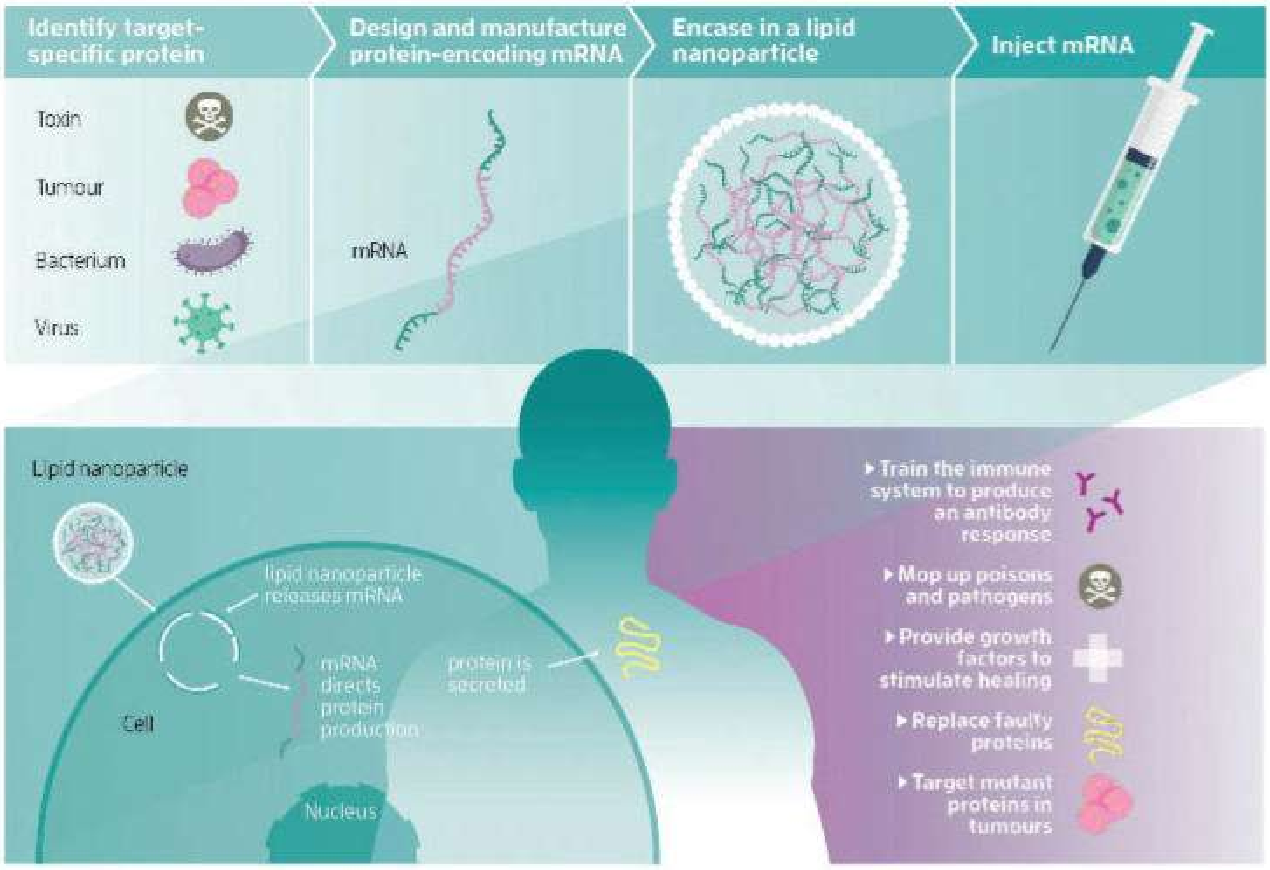
Still, caution is warranted. It is too early to know how much long-term protection mRNA vaccines provide. A UK study found that while the Pfizer/BioNTech vaccine provides higher protection against the delta coronavirus variant than the non-mRNA Oxford/AstraZeneca vaccine, its effectiveness also declines faster. Long-term effects of mRNA vaccines might also turn out to be different to those of other vaccine types, says the study leader Sarah Walker at the University of Oxford.

And while the mRNA covid-19 vaccines have proved safe, they can cause fatigue, headache and fever. There is some evidence that these effects are related to the quantity of RNA injected, says Blakney. Self-amplifying mRNA vaccines, where the mRNAs delivered to cells include one that codes for enzymes that make more copies of the mRNA for the viral protein, could help resolve this. Because they contain less RNA, they might reduce adverse effects and be quicker to make.

Storage is also an issue. Existing mRNA vaccines have to be kept frozen. Cullis thinks it will be possible to keep future mRNA vaccines in a fridge, but doubts room temperature will ever be feasible.

Make your own medicine

mRNA medicines shift the production of therapeutic proteins from factories to the cells inside our bodies, which should make it possible to produce targeted therapies for many illnesses faster and at lower cost


Identify target-specific protein
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Cell
Nucleus
Train the immune system to produce an antibody response
Mop up poisons and pathogens
Provide growth factors to stimulate healing
Replace faulty proteins
Target mutant proteins in tumours

the immune system to target mutant proteins in tumours. But none had yet been approved for human use. The global outbreak proved a crucible for the technology: suddenly there was the urgency and investment required to push it over the line. And there can be no doubt that it has surpassed all expectations. In August, the Pfizer/BioNTech vaccine became the first mRNA vaccine to be fully approved by the US Food and Drug Administration.

Unsurprisingly, now that the power of this technique has been demonstrated in covid-19 vaccines, investors are hurrying to pour in money for other applications. “It’s a gold rush,” says Cullis. “The vaccine applications are quite clearly huge. But in addition to that, you have this ability to express any protein you want.”

Currently, some of our most targeted and potent treatments come in the form of proteins – usually antibodies – that have been carefully tailored to fight a specific condition. Antibodies are what the immune system produces to target disease-causing invaders, but designer antibodies can be used for all kinds of purposes. As well as being designed to stick to mutant proteins on cancer cells, triggering their destruction by the immune system, they can also be designed to help tamp down an overactive immune response as happens in auto-immune disorders.

Antibody-based drugs are already being used to treat these conditions, a range of infectious diseases and even migraines. They can be extremely effective, but the downside is that they are difficult and time-consuming to produce and incredibly costly as a result. These costs can add up to huge sums with conditions that require regular injections of antibodies over many years. The deadly kidney disorder known as aHUS can be treated with an antibody called eculizumab, for example, but it is one of the world’s most expensive drugs, costing some £300,000 a year.

“We can wield the very tactic viruses use against us to treat almost any condition”

The big hope is that, if we can use mRNA to shift the medicine-making step into our bodies, we could produce the same therapies at a fraction of the cost – and produce new ones much faster.

The advantages become clear if we understand the difficulties of making proteins such as antibodies in a factory. The function of proteins depends on them folding into precise shapes, which can only happen correctly in living cells. This crucial shape then has to be carefully preserved during purification and storage, and all of these steps have to be tailored for each different protein. Not so with mRNAs, because it is just the information they encode – the sequence – that matters. They can be made chemically, without living cells, and the same production process can be used every time. “It’s a huge advantage,” says Blakney. “It cuts down on that bottleneck.”

Getting the body to make antibodies directly is a bit different to a vaccine. With a vaccine, only a tiny amount of viral protein is needed and its production has to be limited to one small part of the body because foreign proteins trigger inflammation – shoulder muscles are convenient and safe. For other applications, larger quantities of mRNAs are injected into the blood, where they are almost all taken up by liver cells that produce the specific desired protein and release it into the blood. Essentially, this turns the liver into a bioreactor for producing almost any protein-based drug.

It was only in 2017 that Norbert Pardi at the University of Pennsylvania showed in mice that this was possible, so these kinds of mRNA therapeutics are still at an early stage. Moderna is leading the way. In 2019, the company reported positive results from the first tests in people of an mRNA directly coding for an antibody against chikungunya virus.

And it isn’t just antibodies, but any proteins: in August this year, Moderna started trials for an mRNA coding for a signalling protein designed to treat autoimmune disorders and another that treats an inherited disease by › replacing a faulty enzyme. If these kinds of trials are successful, we could see an explosion of mRNA-based treatments. That would bring many advantages, not least that far fewer injections or infusions of protein therapies should be required. A single dose of mRNA can drive protein production for days, and it is also possible to chemically tweak mRNAs so they persist for longer than that.

Up to speed

Possible lags as therapeutic proteins ramp up to necessary levels for treatment may not actually be so significant either. With mRNAs, there will be a slight delay compared with injecting antibodies directly, but it is so minimal it doesn't seem to matter, even for conditions that require urgent treatment such as poisoning. A recent study in mice, for instance, found that injecting mRNA was just as effective at protecting against lethal doses of botulinum toxin as injecting antibodies directly.

The potential uses of mRNAs will be even greater if we can find ways of delivering them to specific organs or tissues such as the brain or bone marrow. Many genetic disorders are caused by the lack of functional proteins within certain tissues. So far though, getting mRNAs anywhere besides the liver is proving very difficult to do other than by direct injection, says Cullis. But that approach may be good enough for some purposes. Human trials are already under way of Moderna's AZD8601, an mRNA treatment designed to spur blood vessel growth in wounds that won't heal or in tissue damaged by heart attacks, for instance.

Where successful treatment requires getting mRNAs into a higher proportion of cells in a specific tissue or organ than can be achieved by direct injection, there is still some distance to go. One strategy is to put mRNAs inside the empty shells of viruses known to target specific cell types, and so deliver the genetic material into a desired tissue that way. The trouble is that the immune system starts attacking the viral shell, so this method cannot be used repeatedly. In August though, one team reported that it had managed to make viral shells from a human protein, potentially solving this problem. "I think it's definitely doable," says Blakney. "But there's a lot more work that needs to be done."

Then there's the use of mRNA against cancer. The general idea of cancer vaccines is to get a person's immune system to target proteins found on tumour cells, but not healthy cells. Many cancer vaccines are personalised: an individual's cancer is genetically sequenced to identify targets, typically mutant proteins that have arisen in their tumour cells.

The big advantage of the mRNA approach is that cancer vaccines can be produced quickly and relatively cheaply as soon as such targets are identified. But finding targets specific to tumours is difficult, says Smita Nair at Duke University in North Carolina. Nor is it easy to get the body to attack the tumour proteins, because they are similar to those in normal tissue, which are usually off limits to the immune system. "Cancer is much more difficult [than infectious diseases]," she says. "It's a work in progress, but looking hopeful."

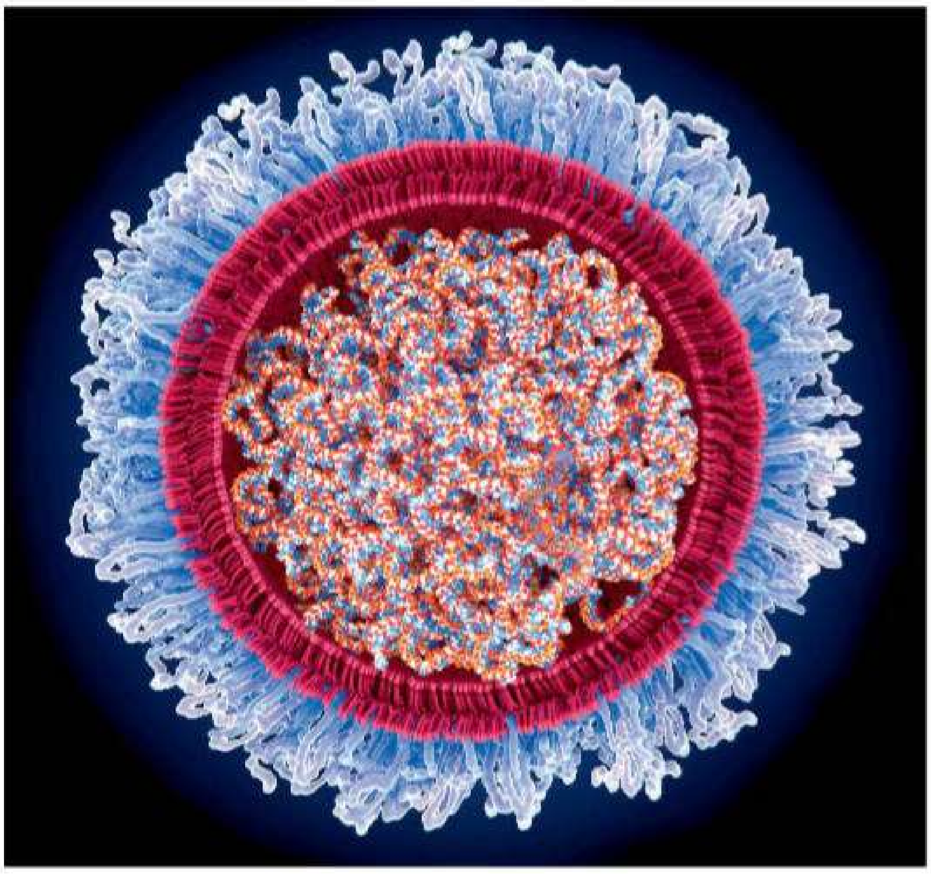
There are currently six ongoing phase II trials of mRNA vaccines for cancer that could potentially lead to approvals, says Jessica McCormack, an analyst with GlobalData. Four of these are personalised vaccines.

While there is no doubt that mRNA vaccines and therapeutics hold enormous promise (see "Injection of hope", page 40), there are reasons for caution. The chikungunya antibody trial remains the only such test of therapeutic protein production in the body so far and the full results haven't yet been published, says Pardi, so we can't yet say for sure that this approach is both safe and effective in people. "Toxicity testing will be absolutely essential," he says.

But all the indications from trials in animals, including non-human primates, are positive, and the potential is staggering. If we can overcome the remaining challenges – and that's a big if – we could wield the very tactic that viruses use against us to treat almost any condition that ails us.

In one sense, there isn't actually a lot that is revolutionary about mRNA vaccines and therapeutics. An mRNA vaccine is a way of getting a viral protein inside the body, as is a subunit vaccine. An mRNA antibody therapy is just a way of delivering an antibody into someone's bloodstream, as is injecting it directly. The end product – the protein – is the same.

But in terms of how fast you can develop and test treatments, and get them to large numbers of people, mRNA technology is utterly transformative. Less than a year after they were first rolled out, mRNA vaccines have already saved hundreds of thousands of lives. "These medicines are just incredible," says Cullis. ▮



Covid vaccines: mRNA recipes are delivered to our cells encased in an oily package

JUAN GAERTNER/SCIENCE PHOTO LIBRARY

Michael Le Page is a *New Scientist* reporter. Follow him @mjflepage

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***Sinosauropteryx* upended the idea that feathers are unique to birds**

China's dinos

Twenty-five years of amazing discoveries in China have changed the way we see dinosaurs – and birds too, says palaeontologist **Michael Benton**

IN OCTOBER 1996, I was in New York City attending the annual meeting of the Society of Vertebrate Paleontology at the American Museum of Natural History. The atmosphere was electric. I recall hurried encounters in hallways featuring black and white photographs and stunned reactions. Yale University's John Ostrom – the leading expert on fossil birds and dinosaurs at the time – said the images left him "in a state of shock". Another dinosaur expert, Phil Currie, then at the Royal Tyrrell Museum of Palaeontology in Drumheller, Canada, described being "bowled over".

At the centre of all the fuss was a specimen that had recently been uncovered in China. No paper had yet been published describing the animal, but Pei-ji Chen at the Nanjing Paleontology Institute had pictures, and they were jaw dropping. They showed a feathered dinosaur – the first ever seen in the West. It confirmed what Ostrom, Currie and others had long been arguing: birds are dinosaurs. As Malcolm Browne wrote in *The New York Times*: "Rarely are scientific findings of this possible importance presented so casually."

Chen's feathered dinosaur, later named *Sinosauropteryx*, was a shock, but nobody could predict that it was the harbinger of a deluge. Since 1996, thousands of specimens of dinosaurs and early birds have emerged from China's Jurassic and Cretaceous fossil beds, most of which are exceptionally well-preserved, including their soft tissues – and especially feathers. This has stimulated 25 years of scientific advances that have not only upended the received wisdom about feathers and birds, but also given new insights into the evolution of flight, warm-bloodedness and dinosaur behaviour.

What makes these fossils so extraordinary is the chemically unusual environment in which they formed. From about 160 million to 110 million years ago, there was continuing volcanic activity in what is now called North

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Cold-blooded no more

Half a century ago, Bob Bakker, then a graduate student at Harvard University, made a startling suggestion: perhaps dinosaurs were warm-blooded, energetic and fast-moving like modern birds and mammals. His idea wasn't well received by other palaeontologists, who had long reconstructed dinosaurs as slow-moving, cold-blooded reptiles. Remarkably, preserved fossils found in China over the past 25 years show Bakker was right.

The Chinese dinosaurs possess many markers of a rapid metabolism, not found in cold-blooded animals. They have air sacs within their vertebrae and limb bones, indicating a birdlike respiratory system. They appear to have had four-chambered hearts, another feature associated with warm-bloodedness. Unlike their reptilian forebears, they stood erect, with their limbs straight beneath the body, enabling them to breathe as they ran. And under the microscope, their bones look like those of birds and mammals, with evidence of fast growth and changing structure.

Even before they could fly, dinosaurs had feathers for insulation, a key requirement for warm-blooded animals to help conserve the heat they have generated. Finds in China suggest feathers emerged with the origins of dinosaurs and pterosaurs, meaning birds and their ancestors were warm-blooded at the same time mammals and their ancestors were becoming warm-blooded too.

This was the moment when life was bouncing back from the devastating end-Permian mass extinction, which wiped out more than 90 per cent of species 252 million years ago. The survivors entered a tough, arid world, and there was an evolutionary arms race as they began to build new ecosystems. This marked a huge shift in the nature of terrestrial ecosystems to the modern form with its high activity levels and increased energy use.

China, a large region north of Beijing. Some animals were buried alive under ash falls, like a prehistoric Pompeii. Many came to rest in ancient lakebeds where fine-grained sediments mixed with enough washed-in volcanic ash to make them acidic, minimising decay and scavenging. It also provided the right conditions to pickle the tougher soft tissues, including feathers, and even preserve internal organs, stomach contents and biomolecules such as proteins, lipids and sugars.

Before the discovery of *Sinosauropteryx*, feathers were thought to be a uniquely avian feature, one of the reasons for the huge success of birds, which now total more than 10,000 species. The Chinese fossils have comprehensively overturned this dogma. When Chen and colleagues published a paper about the fossil in 1998, they identified *Sinosauropteryx* as a compsognathid theropod dinosaur. These are distant from the ancestors of birds in the evolutionary tree, suggesting that hundreds of dinosaur species could have had feathers.

Since then, excavations in China have unearthed some 55 species each of dinosaurs and birds, including more than 30 dinosaur species with feathers. For example, even though fossils show that *Tyrannosaurus rex* had scaly skin, tyrannosauroids unearthed in China had rich feather coverings, so I think we can assume that all members of the group had feathers, at least as juveniles. Perhaps, like elephants and pigs, the young were fluffy and then lost this covering as they grew larger and had less need of insulation. Or perhaps adult *T. rex* still sported feather tufts on the head, or a Mohican-like plume down the back, to intimidate prey or rivals.

Tyrannosauroids are theropods, the flesh-eating dinosaurs that gave rise to birds. But feathers have also been found in China among plant-eaters known as ornithischians. These specimens include the 2-metre-long beaked *Psittacosaurus* and *Tianyulong*, a 70-centimetre-long biped. *Kulindadromeus*, found in Russia in 2014, had closely packed insulating feathers over much of its body, with scaly legs and tail.

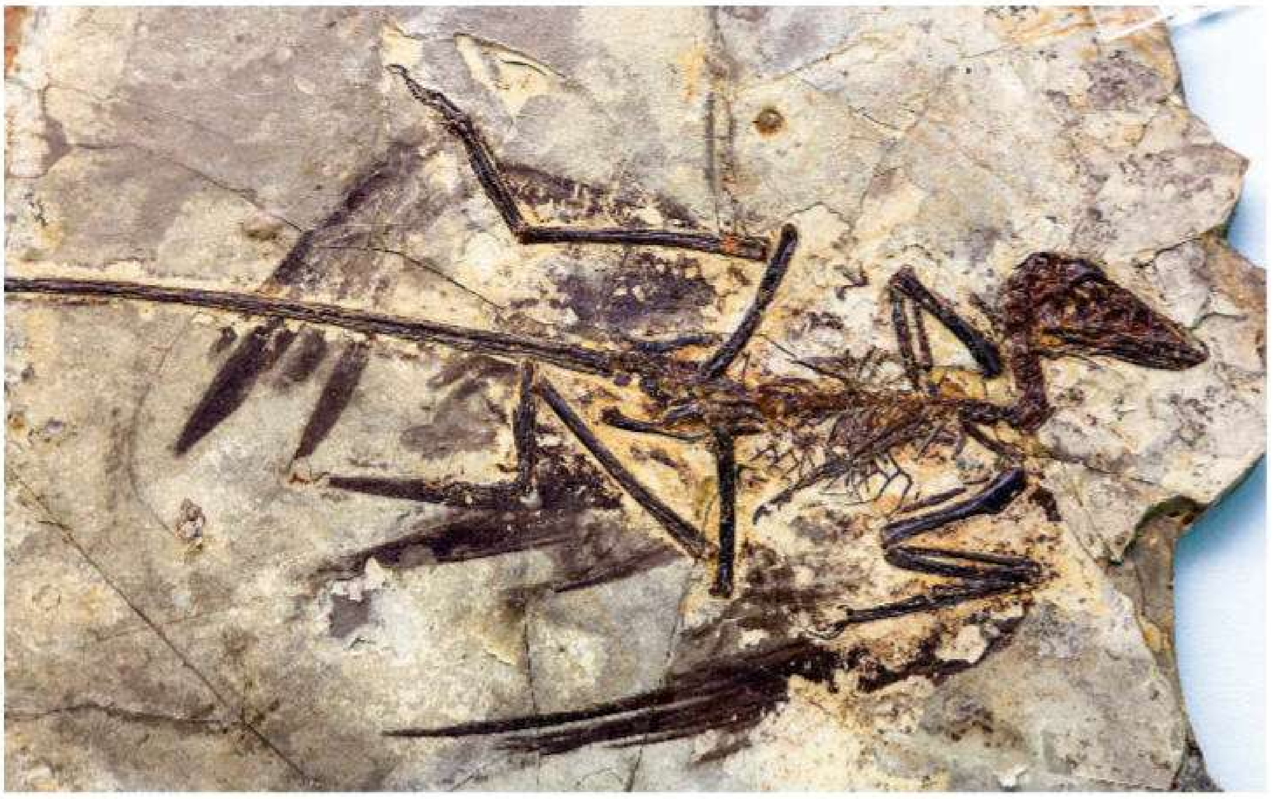
The third dinosaur group, the sauropodomorphs, which includes favourites such as the brontosaurs and titanosaurs, haven't yielded evidence of feathers. This may yet be discovered, but if it isn't, it is still likely that feathers originated with dinosaurs back in the Early Triassic, some 250 million years ago. That's because identical feathers occur in dinosaurs at opposite ends of the family tree, so their common ancestor almost certainly had them.

Feathered pterosaurs

Other animals from the period may have had feathers too. The pterosaurs aren't dinosaurs but their cousins, and they also originated in the Early Triassic. These leathery-winged flyers had a covering of bristles over their heads and bodies. In 2019, my colleagues and I identified multiple feather types in pterosaurs – some simple bristles as had been reported before, but also some that showed the same branching and structural shapes seen in dinosaurs. We called them feathers, but others aren't so sure. Either way, the evidence suggests feathers arose long before the origin of birds.

The Chinese fossils haven't changed our thinking about when birds evolved: *Archaeopteryx*, which lived 150 million years ago, in the Late Jurassic, is still widely accepted as the first bird. But they have given us a much richer picture of bird evolution. Back in 1996, there was a long gap in the fossil record between *Archaeopteryx* – which had reptilian features, including jaws lined with teeth and a long, bony tail – and more modern birds dating from around 80 million years ago. This gap has now been filled with dozens of species of birdlike dinosaurs and early birds, the latter being distinguished by 30 or so distinctive traits, including specialised wrist joints to fold back the wings, hollow bones to save weight and a fused clavicle or wishbone.

As well as enhancing our understanding of how and when birds evolved, the evidence from China leaves no doubt that birds are dinosaurs. It identifies a major new group of dinosaurs within the theropods called the paravians, which includes birds and little birdlike dinosaurs. It also reveals that many



STEVE VIDLER/ALAMY

CHRISTIAN DARKIN/SCIENCE PHOTO LIBRARY

***Microraptor* (left and below) is one of the Chinese dinosaurs that shows flight evolved at least three times**

traits associated with birds have deep roots in non-avian dinosaurs. Not least of these, of course, is the feather.

The discovery of feathered dinosaurs doesn't just overturn the dogma that feathers are unique to birds, it also provides some intriguing insights into the lifestyle of the dinosaurs that sported them. Feathers have multiple functions in birds, including insulation, flight and display. The first dinosaurs certainly weren't flyers, but the Chinese fossils resolve a long-standing debate, confirming them to be warm-blooded (see "Cold-blooded no more", left). Warm-blooded animals need to preserve the precious heat they generate, so insulation looks to be the reason feathers first emerged.

Display seems to have come later. We now think that the smaller feathered dinosaurs probably hopped and preened and flashed beautifully coloured head crests, tails and wing patterns to attract mates. This was true even of the short-armed, non-flying forms such as *Sinosauropteryx*, as my colleagues and I showed in 2010. If you put fossil feathers under a scanning electron microscope, you can see tiny pigment capsules called melanosomes. The pigment melanin is present in many organisms, and it takes two main forms in birds and mammals: phaeomelanin, which provides shades of ginger, and the more common eumelanin, which appears black, brown, grey or blonde depending on how densely it is packed.

Melanins are generated in the skin and enter developing hairs and feathers via the follicle, becoming encased in spherical phaeomelanosomes or sausage-shaped eumelanosomes. When we looked at feathers from the body of *Sinosauropteryx*, we saw only phaeomelanosomes – evidence that they were originally ginger, with a tail that was barred ginger and white. Other dinosaurs had red crests, black and white stripes on their wings and multicoloured mottles over the body.

Feathered dinosaurs included the plant-eating *Psittacosaurus* (directly below) and carnivorous *Sinosauropteryx* (bottom)

DPA PICTURE ALLIANCE/ALAMY

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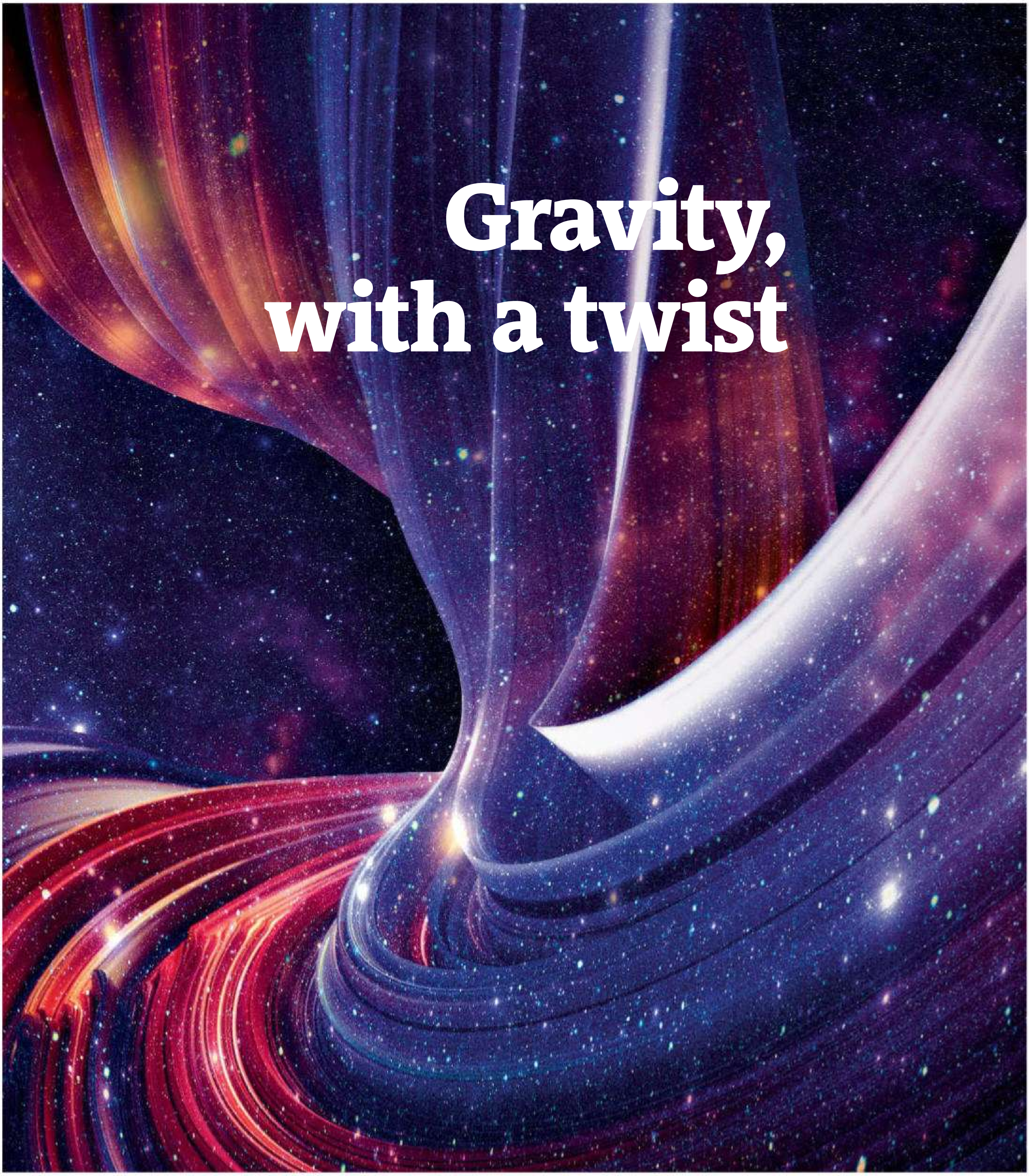
As for flight, the Chinese fossils are shedding new light on that, too. In 2020, a study exploring the aerodynamics of early birds and their close relatives revealed that flight evolved not once but at least three times. To fly, a creature's wing area must exceed a critical point at which it can support the body weight. Paravians did this in various ways. *Archaeopteryx* and its kin had two feathered wings, while discoveries in China show that *Microraptor*, which lived around 125 million years ago, had four wings and its contemporary, *Yi qi*, had batlike membrane wings. This diversity has its origins around 175 million years ago when theropod dinosaurs underwent a dramatic evolutionary split in which most – like *T. rex* – became larger to overpower ever-larger herbivore prey, while the paravians shrank in size, probably in pursuit of insects, and modified their feathers for flight, camouflage and display.

Discoveries in China have immensely enriched our understanding of dinosaurs and early birds: what they looked like, their colours and mating displays, how they got around and how they are related to one another. A quarter of a century on from the astonishing revelation that dinosaurs can have feathers, fossils continue to emerge in large numbers in China. Who knows what revelations they will bring in the next 25 years. ∎

Michael Benton is at the University of Bristol, UK. His book, *Dinosaurs: New visions of a lost world*, is published this month by Thames & Hudson



Gravity, with a twist

ANDREY A/SOLOLOS/ISTOCK

Albert Einstein once proposed that space-time was more twisted than even he had supposed. This long-forgotten idea might just solve today's crisis in cosmology, says **Paul M. Sutter**

LONG ago, people thought that empty space was just what it sounds like: a featureless void. But the more we have studied seeming emptiness, the more we have shown that this is far from the truth. The air around us is full of jostling gas molecules. In space proper, beyond our atmosphere, there are quantum fields and particles of light. Even the emptiest corner of interstellar wilderness isn't devoid of character because space itself can warp and curve.

But what if we still haven't got to the bottom of what space is like? In the middle of his career, Albert Einstein became convinced that general relativity, his great theory of space and time, had missed a trick. Yes, space did warp and curve – but not in the way he had thought. If the true twistiness of space was accounted for, he reckoned, it might bring us closer to a grand unified theory of physics.

Einstein never quite cracked the idea, and it has been largely left to languish for almost a century. But now there is fresh cause to revive it. Physicists are struggling with a raft of devilish problems in cosmology that are forcing us to question the basics of even our most well-established theories. Dark energy, the unidentified stuff that seems to be pushing the universe apart at an ever accelerating rate, is just one example.

Some physicists are asking whether the answer to all these problems could be to once again tweak our understanding of space itself. This time the goal isn't to unify all of physics. But if we give space the right kind of twist, it is beginning to look like many of the most vexing problems in physics could melt away.

The way we now understand space dates back to 1915, when Einstein published his theory of general relativity. It is built upwards from his realisation that the way objects respond to gravity and acceleration is indistinguishable, which we now call the equivalence principle. The theory tells us that space and time can't be considered separately, but only as a kind of four-dimensional canvas for reality.

As if that wasn't enough, Einstein also showed that any object with mass could warp and deform space-time, like a higher-dimensional version of a bowling ball on a trampoline. It was these undulations in space-time that gave rise to gravity. Objects falling from the sky were following invisible contour lines in the fabric of space. It is a beautiful theory that has stood the test of time. But for Einstein himself, trouble was already brewing.

In the early 1920s, he and others were laying the foundations for the most successful idea in all of physics: quantum theory. It explains the nature of the subatomic world, including electromagnetism, the force that gives rise to light and creates attractions and repulsions between charged particles. From the start, this theory forced us to leave common sense at the door. It works by predicting what will happen when an observer makes a measurement on a quantum particle, and seems to suggest that before that measurement, the particle exists in a nebulous cloud of indeterminacy. Einstein liked it not one bit; he thought the chance and imprecision at the core of the theory was a sign of our ignorance, not a true aspect of nature.

So he began work on an alternative theory of electromagnetism, one written in similar mathematical language to general relativity.

> "Massive objects would cause space-time to twist up beneath them, like a cyclone in the fabric of reality"

To understand how it works, we need to know that mathematicians have two ways of talking about how things curve. One is simply called curvature and it describes how lines bend. Then there is a more sophisticated language called torsion, which is used to describe how things twist. You could describe a piece of wiggly spaghetti on a plate with curvature, but to define the corkscrew shape of fusilli you would need torsion.

In general relativity, Einstein had found that using a 4D version of curvature to describe space-time worked perfectly. His new plan was to develop a version of the theory using torsion instead and see if this could explain both gravity and electromagnetism in one neat package. It was a delightful idea. In the new hypothesis, massive objects and charged objects would cause space-time to twist up beneath them, like a cyclone in the fabric of reality. They would do this in slightly different ways, one giving rise to electromagnetism and the other gravity.

Einstein published this hypothesis in 1928. But he couldn't get it to work properly – the rewritten theory was really just general relativity expressed in a new way and it couldn't explain electromagnetism. It is known as teleparallel gravity because of the way it was initially analysed by examining parallel lines in space.

In the decades that followed, teleparallel gravity was worked on by the occasional theorist. Meanwhile, general relativity scored success after success and quantum theory matured and dominated fundamental physics. Interest in Einstein's attempt at unification waned.

Today, physics is in a wholly different place. General relativity and quantum theory continue to be confirmed time after time. Yet it seems they can't be the complete description of reality because they are mutually incompatible. There are also huge problems in cosmology that they can't answer (see "Four problems, one solution", page 49).

One of them first appeared about 20 years ago, when astronomers noticed that the rate of expansion of the universe is accelerating. We have no good explanation for this apart from to invoke an unknown substance called dark energy. The past few years have thrown up an even more embarrassing problem. We measure the rate of expansion of the universe using two different methods, one based on exploding stars and one based on the cosmic microwave background, a sea of radiation

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emitted shortly after the big bang. These two methods give us two quite different answers. It is still just possible that this trouble, known as the Hubble tension, could be down to a measurement error. But it is fair to say that cosmologists are in crisis mode.

One resolution might lie in accepting that general relativity doesn't provide a perfect description of reality. In this reading, there is no dark energy – it is just that gravity itself doesn't work quite how we thought it does.

Theorists have been producing modifications to general relativity for decades. Most focus on adding new ingredients to the formula, allowing the curvature of space-time to respond to more than the presence of matter and energy. But with so many flavours on offer, how do you discern if any are correct?

One way to judge involves gravitational waves, fluctuations in space-time that result from collisions between stars, black holes and the like. General relativity says that these waves should propagate at the speed of light. But modified theories of gravity almost always predict a slightly slower speed.

In 2017, we managed to observe the gravitational waves caused by the smashing together of two neutron stars – and the light that this produced. The flash of light and the gravitational waves arrived at Earth within seconds of each other. There was no slowing, and this result was enough to wipe almost every theory of modified gravity off the table.

Last one standing

But not teleparallel gravity. The theory doesn't predict any change to the speed of gravitational waves. This means that, for those who think the Hubble tension can be resolved by overhauling gravity, there are few options left except teleparallel gravity.

It is this kind of logic that motivates people like Jackson Said at the University of Malta, a leading figure in teleparallel research. "These are very exciting times, with a new synergy in the community in getting teleparallel gravity to help solve some of the big problems in modern cosmology," says Said.

He isn't alone in his enthusiasm. "As a cosmologist, I find teleparallel gravity very intriguing," says Celia Escamilla-Rivera at the National Autonomous University of Mexico. "We are excited that it can shed some light on the questions that have been problems for several years in cosmology, like the nature of the dark sector."

ANDREY A/SOLOLOS/ISTOCK

We have known for a long time that the equations of general relativity can be written down using the language of torsion as well as curvature, and the two work out as equivalent. This was proved back in 1976. It means that if Einstein had chosen to use torsion to write out his equations from the very start, his theory would still have worked just as well.

The audacious hope is that teleparallel gravity is actually better than general relativity. The mathematical language of torsion is more malleable than curvature, so researchers can fit terms into the equations that make matter and energy more responsive to the twistiness of space-time. In almost all circumstances, including the ordinary space in our solar system, these modifications make no noticeable difference to anything. But they would kick into gear in extreme situations, like at the big bang or on the epic scales of the entire universe – exactly where we encounter the biggest problems.

In 2018, astrophysicist Rafael Nunes at the National Institute for Space Research in Sao Paulo, Brazil, used teleparallel gravity to explore the Hubble tension. He tried a simple modification to basic teleparallel gravity and used this framework to calculate the rate of the universe's expansion from data on the cosmic microwave background. It came out the same as the rate given by supernovae. The Hubble tension had melted away.

There are now published models of teleparallel gravity that can explain away three other big problems in cosmology too. But these each use different modifications – there is no single theory of teleparallel gravity.

Recently, however, there has been a finding that boosted the case for teleparallel gravity, one that circles back to Einstein's original vision. One of the leading candidates for a unified theory of physics today is string theory, which says that all forces and energy in the universe arise from the vibrations of invisible strings. The theory is much maligned for its lack of testable predictions and intractable mathematics. But with a dearth of strong competitors, it still commands plenty of interest as a possible theory of everything. If it is, then a new theory of gravity should be derivable from string theory.

Earlier this year, a team of theorists led by Sebastian Bahamonde at the University of Tartu in Estonia found that teleparallel gravity is contained within string theory. They used mathematical language borrowed from string theory to derive a teleparallel-based history of the universe, and found that it mimicked many key features of our cosmological past. It is far from a closed case, but is another hint. "We do not expect that general relativity is the final theory of gravity," says Bahamonde.

Cosmologist Eleonora Di Valentino at Durham University, UK, is paying close attention to teleparallelism. "My point of view is that at this stage all the possibilities are welcomed," she says. "Teleparallel gravity is a quickly growing, but still very theoretical, field."

Testing teleparallel gravity is the only way we will find out if it is correct. But that won't be

Four problems, one solution

Cosmology is facing four huge, interrelated problems. A resurgent theory called teleparallel gravity might provide answers to them all

PROBLEM 1:
DARK MATTER

Beginning in the 1970s, astronomers began to realise that many galaxies are rotating so fast that they ought to spin themselves apart – unless, that is, they contain extra, invisible matter. Further evidence has led us to believe that this dark matter makes up more than 80 per cent of all matter in the universe – but we don't know what it is.

PROBLEM 2:
INFLATION

In order to explain how uniform the universe is on the largest scales, cosmologists think it ballooned at incredible speed soon after the big bang. But what triggered this period of inflation and what switched it off? One hypothesis involves a quantum field that has since disappeared for unexplained reasons.

PROBLEM 3:
DARK ENERGY

In 1998, we discovered that the universe's rate of expansion is accelerating. So far, all cosmologists have been able to do is give this phenomenon a name: dark energy. We have very little idea what it actually is.

PROBLEM 4:
THE HUBBLE TENSION

We can measure the present-day expansion rate of the universe – known as the Hubble constant – in two ways, one based on nearby supernovae and another based on radiation left over from soon after the big bang, called the cosmic microwave background (CMB). The latter method gives a number that is about 10 per cent smaller than that given by the former.

SOLUTION:

Under teleparallel gravity, there is no need to invoke dark matter or dark energy. Instead we have a different picture of how ordinary matter responds to gravity. Inflation still happens, but it is a natural consequence of the state of the early universe. The Hubble tension also disappears. If gravity operates differently to how we think on the largest scales, then we would need to tweak the way we analyse the CMB. Indeed a version of teleparallel gravity has already been shown to resolve the Hubble tension in principle (see main story).

easy. The idea comes in so many flavours that no single test would prove it right or wrong. Instead, progress is more likely to come from tests that push general relativity past its breaking point. So far, Einstein's theory has proved singularly resilient, even describing extreme scenarios like the collisions of black holes to perfection.

Mysterious equivalence

There may be one way to directly test teleparallel gravity and that is through the equivalence principle, the bedrock idea on which general relativity is built. The principle says that an object's gravitational mass, which responds to the warping of space-time, is the same as its inertial mass, which resists acceleration.

In general relativity, the equivalence principle has to be true, or the theory collapses. But there has never been an obvious reason this is so. All we know is that, empirically, the principle is sound – at least in all measurements we have made so far.

One manifestation of the principle is that all objects fall to Earth with the same acceleration regardless of their mass, as long as things like air resistance don't interfere. We already know this is true to an accuracy of one part in a trillion. But if we found even the tiniest difference, that would show that general relativity is wrong and point strongly towards teleparallel gravity.

There is one proposed experiment that might just be capable of checking this. The Satellite Test of the Equivalence Principle project aims to put eight different test masses into orbit, shield them from drag and measure how they respond to Earth's gravity in minute detail. If any difference appears between the behaviour of the masses, that would be a violation of equivalence – and teleparallelism will be right there waiting to explain the results.

Einstein himself never gave up on finding an alternative to quantum theory until his death in 1955. His forgotten theory isn't what he once hoped it could be. But it is possible that his twisted vision of space wasn't entirely wrong. For now, at least, Einstein's dream is still alive. ■

Paul M. Sutter is an astrophysicist at Stony Brook University in New York. His latest book is *How to Die in Space* (Pegasus Books)

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Citizen science

Ancient atmospheres

Try out time travel to help researchers predict how climate change will affect Earth's future, says **Layal Liverpool**

Layal Liverpool is a science journalist based in Berlin. She believes everyone can be a scientist, including you. @layallivs

What you need

Access to Fossil Atmospheres via zooniverse.org

IF YOU could time travel, which period from history would you choose to visit? I recently took a trip back to the Palaeocene-Eocene thermal maximum – a time period about 56 million years ago during which a huge amount of carbon dioxide was released into Earth's atmosphere, causing the average global temperature to rise by about 5°C.

Many scientists are interested in how this drastic change affected life on Earth, not least because knowing more about it could help us better predict the impacts of current and future climate change. You can assist them by taking the same trip I did, and participating in the Fossil Atmospheres project.

Head to the zooniverse.org web portal for citizen science and search for "Fossil Atmospheres" to get started. You will be asked to label cells in microscope images of modern and fossilised leaves from ginkgo plants. These unique, non-flowering seed plants have been around for hundreds of millions of years. A handy tutorial on the website can guide you on how to distinguish the different types of leaf cell, so don't worry if you aren't a cell biology whizz.

Your labelling will help researchers to calculate what proportion of leaf cells are made up of stomata – pores on the leaf surface that allow uptake of CO_2. They can then use this to estimate what the environmental CO_2 levels were at the time the plant lived.

"Plant leaves are extremely sensitive to the composition of the atmosphere," says Richard Barclay, a palaeobotanist at the Smithsonian Institution in Washington DC and lead researcher on the Fossil Atmospheres project. That is because plants use CO_2 to make the sugar they need to grow.

RICHARD BARCLAY/FOSSIL ATMOSPHERES PROGRAM

When the concentration of CO_2 in the atmosphere changes, it affects plant productivity and they adjust the shape of their leaves and the size and number of pores on the leaf surfaces.

Barclay and his colleagues have collected hundreds of leaves, producing many images of each – far more than they can analyse on their own. Since Fossil Atmospheres first started in 2016, citizen scientists have helped the team analyse almost 128,000 images. The researchers are using the data to create a record of how Earth's atmosphere has changed over time, as well as how it is continuing to change.

"We study climate change events in the geologic past, and they have eerily similar patterns to what we observe happening today," says Barclay. The key difference is that this time, the climate is changing much faster, he says.

Important information about how plants will fare in this uncharted world may be hidden among the thousands of leaf images online. What is needed now is for as many citizen scientists as possible to log on and get counting. ▮

Citizen science appears every four weeks

Next week

Science of cooking

These articles are posted each week at newscientist.com/maker

New Scientist
Discovery Tours

7 days | 18 January 2022

Norway: Wonders of the Arctic

Norway boasts some of the most beautiful natural experiences, home to the northern lights as well as a rich diversity of marine life in its fjord coastline. On this New Scientist Discovery Tour, you will gain an in-depth insight into the science behind the Aurora Borealis and the behavioural ecology of the humpback and orca whales.

Accompanied by marine biologist Helen Scales and plasma physicist Melanie Windridge. You will explore Norway's iconic fjords by boat, where you can meander through the frozen forested valleys from the picturesque city of Bergen at their heart. You will travel north and stay in an observatory where you can witness and learn about the splendour of the northern lights.

Highlights

- Marine biologist Helen Scales will give evening talks and accompany you on a cruise from Bergen along the Osterfjord to the rugged Mostraumen fjord.
- Plasma physicist and STEM ambassador Melanie Windridge will accompany you during your two night stay at the Aurora Borealis Observatory on Senja Island. Here you will enjoy stargazing outdoors and talks about the northern lights and the science behind fusion energy where researchers are trying to replicate the nuclear reactions which take place inside the stars themselves.
- A walking tour of Bergen, the most beautiful city in Norway. Explore charming wooden streets, Vågen harbour and the Bryggen quarter, now a UNESCO World Heritage Site.
- Wildlife fjord safari by boat where, as you pass through the frozen coastline, you will get an opportunity to look for sea eagles, seals, elegant cormorants and whales (orca and humpback).

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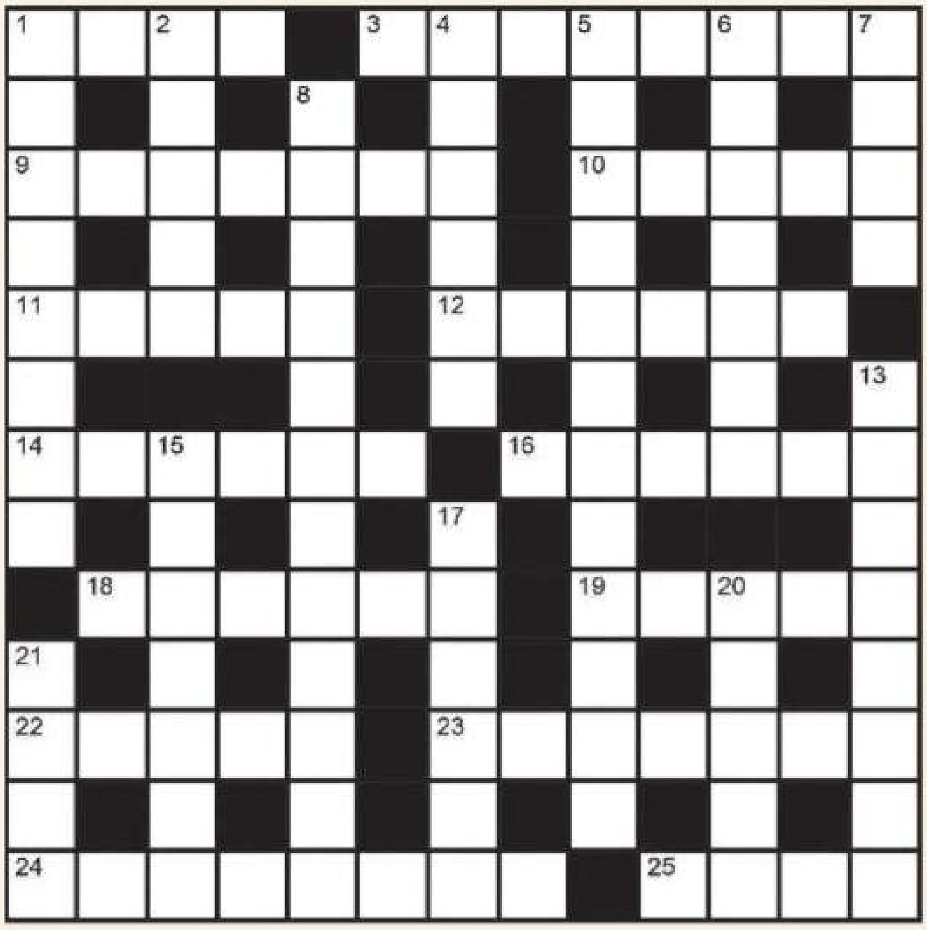
Cryptic crossword #68 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Wasting time in extremely trendy London district (4)

3 Clutching limb, awkwardly smote monkey (8)

9 One way to send Spooner's municipal leader beer (7)

10 Overburden working class, for one (5)

11 Bewildered dad doesn't finish final letter (5)

12 Tolkien baddie concealed lady's slipper, for example (6)

14 Seaweed I blended essentially safe to consume (6)

16 Possibly take possession of flat molybdenum lode (4,2)

18 Medal-worthy rock choir holding note (6)

19 Decorative item tied back (5)

22 Skipped broken plate (5)

23 Increasing energy level of non-Catholic leaving stage (7)

24 Some rags shredded like spiderwebs (8)

25 Short ski at the old Scottish place (4)

DOWN

1 Bound south, walked like an emperor? (8)

2 Discoverer of radio waves is sore, we hear (5)

4 Flowering laurel finally in a growth period (6)

5 With German in *el laboratorio*, eight drain faulty cell components (12)

6 Destroyed files describing former lover, and what was shared with them? (3,4)

7 Part of knife pest returned (4)

8 Italian poet skirts sandwich shop, only half-finished with a botanical drink (9,3)

13 Undigitised article Angelou reworked (8)

15 Space cowboy's first one climbing polar features (3,4)

17 Plan lab course probing frontiers of science (6)

20 Pain-in-the-neck partner of Watson (5)

21 Ascending seabirds dropping one large gastropod (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #123

1 What name is given to a sudden, sharp increase in wind speed of 8 metres per second or more and that lasts for longer than a minute?

2 Who was the first person to spacewalk?

3 What unusual discovery took place on Similaun, a mountain on the Austrian-Italian border in 1991?

4 Transactinide elements have atomic numbers greater than what?

5 Which vital hormone is primarily produced by the pineal gland?

Answers on page 55

Puzzle

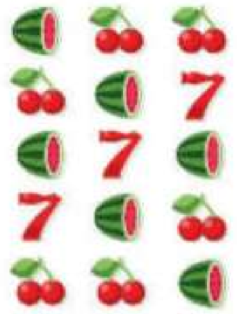
set by Brian Hobbs

#135 You don't know jackpot

I figured something was wrong with the slot machine in Pete's Gas Station when I saw the peeling paint on top. But I knew for certain when I put in 50 cents, got three 7s, and nothing came out.

There are three possible symbols: cherries, a melon and a 7. It should have given me $5 for all three 7s, $2 for two 7s, and $1 if only the rightmost symbol was a 7.

"Oh, it's fine," said Pete. "Three 7s was the old jackpot setting. I've got the new jackpot written down… it's here somewhere." While he was searching, I saw a woman play five times and get the following:



"House always wins," she muttered before leaving. Pete wandered in: "Sorry, can't seem to find it." "No problem," I said. "I think I've got it." What is the jackpot setting?

Solution next week

Absolute heat

If absolute zero is the lowest possible temperature for matter, is there an upper limit or highest possible temperature?

Garry Trethewey
Cherryville, South Australia
The temperature of a substance, whether solid, liquid, gas or plasma, is essentially related to the speed at which its particles are moving in relation to each other. There is an upper limit on speed – the speed of light.

Vlatko Vedral
University of Oxford, UK
There are a number of arguments as to why there should be an upper bound on the value of temperature. The simplest is that temperature is related to energy (via Boltzmann's constant). So if we believe that the energy in the universe is finite (a reasonable supposition), then that gives us the highest temperature.

This can be estimated as follows: the mass of the visible universe is about 10^{54} kilograms. From this, the energy of the universe can be calculated using the equation, $E = mc^2$, where energy (E) equals mass (m) multiplied by the square of the speed of light (c^2). Then divide this sum by Boltzmann's constant to get the temperature. This comes out to about 10^{94} kelvin. While this is a large number, it certainly isn't infinite.

> **"It is possible that neither the lowest nor highest temperature will ultimately have any fundamental significance"**

The second argument comes from quantum physics and gravity. They imply that there is a smallest possible distance that can be defined in the universe, known as the Planck length. This gives us the highest possible frequency, which when multiplied by the Planck constant gives us the highest possible quantum of energy. If you divide this by Boltzmann's constant, you get a temperature of 10^{32} kelvin. This is sometimes called the Planck temperature.

Another way of thinking about this concerns the Planck mass, thought to be the highest mass that a hypothetical elementary particle could have. Multiply this by c^2 to get the energy of this particle, then divide by Boltzmann's constant and you again get the Planck temperature, 10^{32} kelvin. This is much smaller than the first estimate I presented, but some cosmological models take it to be the initial temperature of the universe.

However, temperature isn't a fundamental entity. It is really an emergent concept that tells us about the average chaotic kinetic energy of an object. In that sense, it is perfectly possible that neither the lowest nor the highest temperature will ultimately have any fundamental significance. Only time will tell.

What would the ecological fallout be if mosquitoes were wiped off the planet?

NECHAEV-KON/GETTY IMAGES

This week's new questions

Time to panic **We are often told that "now is not the time to panic" when a crisis is looming or happening. When is the right time to panic?** ***Peter Slessenger****, Reading, Berkshire, UK*

Buzz off **From a human perspective, mosquitoes don't have many positives. What would be the ecological consequences if they were eradicated?** ***Ian Jarvis****, Saffron Walden, Essex, UK*

Baking boundaries

Scientifically speaking, what is the difference between a cake, a biscuit and a sponge?

Andrew Keen
Harcourt, Victoria, Australia
A French chef once responded to this question in a cookery class. In order to tell the difference, they said, leave the unknown samples out overnight. In the morning, if the sample is hard, it is cake. If it is soft, it is a biscuit. Voila!

Hazel Beneke
Banksia Beach, Queensland, Australia
A cake becomes harder as it ages because of water loss. But a biscuit becomes softer because it absorbs water.

Joan Zealey
Wollongong, New South Wales, Australia
To quote Mrs Beeton, the Victorian cookery writer, "true sponges contain no fat", only eggs (which actually contain a bit of fat) and sugar whipped to an emulsion with some flour gently folded in so as not to disturb the bubble structure of the mixture. All other types of cake contain added fats.

Averell Kingston
Banbury, Oxfordshire, UK
It is amazing how many different edible items can be made from the same four basic ingredients: flour, sugar, eggs and fat. The variety is the result of several factors, including the relative amounts of the ingredients in the recipe, preparation technique and, to a smaller extent, cooking method.

The light, easily crumbled texture of cake relies on a few things. The structure is composed of two types of large molecule: starch (flour) and protein (eggs). When heated with moisture, these form a lattice-like arrangement. Sugar and fat partly fill the holes, but leave some air spaces, resulting in a light texture. Too much sugar and fat will cause the starch-protein lattice to collapse, producing a heavy cake.

Traditionally, the fat used was butter, which had to be beaten with sugar for a long time (up to an hour in some old recipes) to incorporate air. Eggs also needed to be beaten for a long time to get in as much air as possible. In the early 20th century, the hydrogenation of vegetable oils produced softer fats that could be beaten with sugar much more

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Tom Gauld
for New Scientist

THE LEAD RESEARCHER JOB? YOU'VE GOT TO BE KIDDING, LINDA! YOUR EXPERIMENTS ARE RECKLESS AND YOUR SAFETY RECORD IS ABSOLUTELY APPALLING.
I'LL BE HONEST: THE ONLY WAY YOU'D EVER GET THE JOB WOULD BE IF EVERYBODY ELSE IN THE LAB DROPPED DEAD.
WELL, THAT BRINGS US RATHER NEATLY ON TO THE SECOND THING THAT I NEED TO TALK TO YOU ABOUT...

easily, so producing lighter cakes.

During cooking, the cake batter expands as the raising agent (sodium bicarbonate) produces carbon dioxide, while the water turns to steam. Meanwhile, the egg proteins coagulate and the starch granules absorb water and form a gel. Both these processes make the batter set.

The lightness of sponges depends on eggs and sugar being beaten together for at least 10 minutes to incorporate lots of air and produce a thick, mayonnaise-like substance. Flour and melted fat are then carefully stirred in so the air isn't displaced. The sponge needs to be cooked straight away.

Biscuits usually contain only flour, sugar and fat, with possibly a small amount of egg. Without the starch-protein lattice, the result will inevitably be firmer.

Isabella Van Damme
Highland, UK

Cakes, sponges and biscuits are all examples of heat-induced protein and starch networks, each containing a different volume of air. Cake and sponge both contain a large amount of air and have a fine crumb structure.

> **"It is amazing how many different edible items can be made from the same four ingredients: flour, sugar, eggs and fat"**

Basic biscuits are a mixture of fat, sugar and flour without eggs or other raising agents. As a result, biscuits contain a low volume of air that is often trapped in cracks or irregular air cells rather than the more spherical air cells in cake and sponge. Biscuits have a coarse, crumbly structure as the fat, sugar and flour form aggregates.

Grinning mammals

Grinning or baring the teeth is usually a sign of aggression in animals, so at what point did it become advantageous for humans to use this to signal friendship or mirth? (continued)

Alex Fraser
Bodmin, Cornwall, UK

Further to the responses about grinning mammals (28 August), I would like to add that Dalmatian dogs are renowned for their ability to "smile". To the uninitiated, this can look like a grimace, but in my experience, this is how my Dalmatian expresses happiness and excitement. It is often displayed when greeting an owner after an absence.

A smile is usually accompanied by extreme tail and body wagging, hence I am unable to provide any photographs to support my claim. Any attempt of mine to take such an image results in a blur of dog that is completely indiscernible, though plenty of photos can be found through an internet search.

Talia Morris
Cape Tribulation, Queensland, Australia

In many animals, particularly non-human primates, smiling or grinning is a sign of fear and submission, commonly shown to their social superiors. ▮

Answers

Quick quiz #123
Answers

1 A squall
2 Alexei Leonov, during the 1965 Voskhod 2 mission
3 The discovery of Ötzi the Iceman, the naturally mummified body of a prehistoric man
4 103
5 Melatonin

Quick crossword #93
Answers

ACROSS 1 Sharps, **4** Formalin, **9** Mothra, **10** Cyanotic, **12** Nonagons, **13** Nature, **15** Stanislaw Lem, **18** Testosterone, **21** Ipecac, **22** Periodic, **24** Glaucous, **25** Almond, **26** Selenium, **27** Stress

DOWN 1 Sameness, **2** Antennae, **3** Peregrine falcon, **5** Onyx, **6** Manganese violet, **7** Litmus, **8** Nickel, **11** Inflate, **14** Twister, **16** Cold sore, **17** Mercedes, **19** Biogas, **20** Recall, **23** Zulu

#134 No time to try
Solution

There are 24 ways of arranging four digits ABCD (such as ABDC, ACBD etc), but there are 36 ways of arranging three digits into a four digit number (AABC, ABAC, BBAC etc), so James Blond should go for Door 1 with the four worn digits as he will only need 24 attempts at most to crack the code.

Acting up

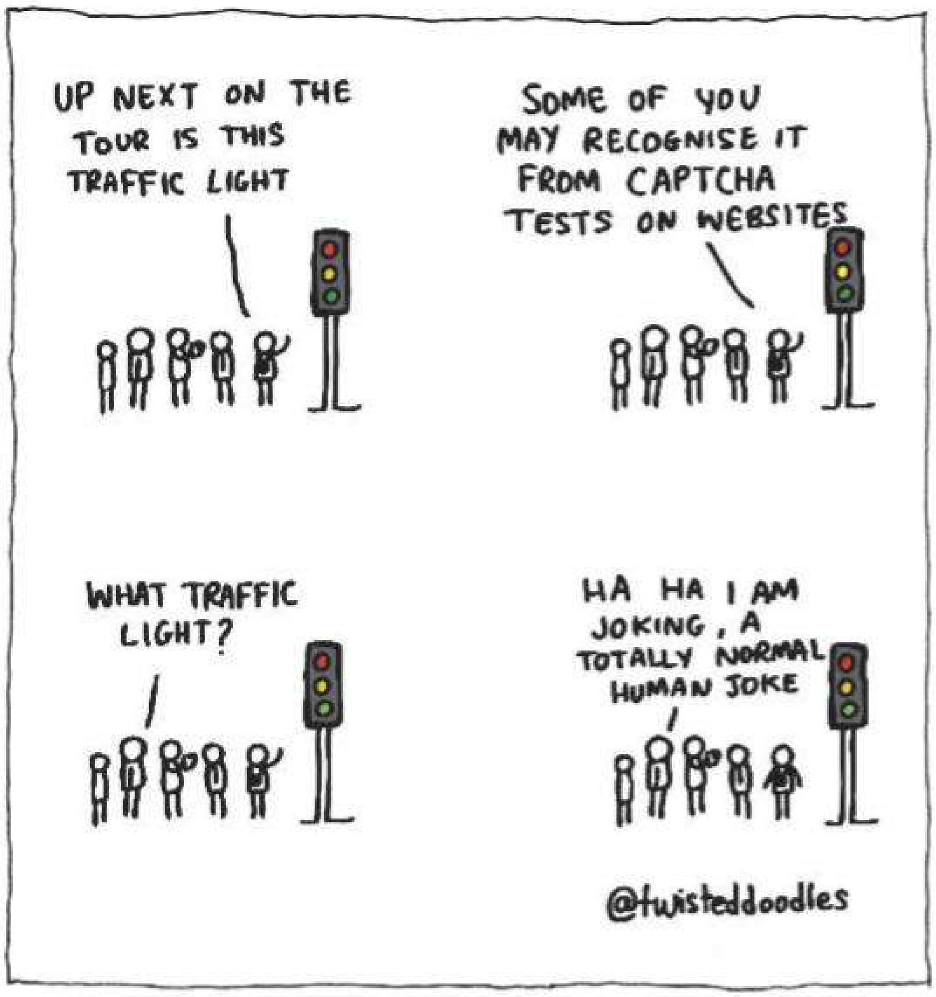
After the recent excitement of Richard Branson and Jeff Bezos battling to be the first billionaire to fly on self-funded rockets, you would be forgiven for thinking that 2021 has already delivered enough in terms of space races. But then, like an online purchase you made months ago and forgot was due, a new one has turned up: who would be first to make a feature film in orbit?

The title initially looked set to be claimed by *Mission Impossible* star Tom Cruise, who since last year has been planning an October trip to the International Space Station (ISS). Now a rival movie team has beaten him to it, having arrived at the ISS last week to make an action adventure of their own. Adding to the theatre for onlookers from the Hollywood cliché department is the fact the rival team is Russian.

Cruise's exact launch date hasn't yet been announced, but if the two movie teams overlap, things could get awkward on the cramped space station. While details of Cruise's film are a closely guarded secret, the Russian space agency Roscosmos said its drama would "popularise Russia's space activities, as well as glorify the cosmonaut profession" when it began casting last year.

Not all are in favour of the ISS's new role as a film set. Russian cosmonaut Mikhail Kornienko told the BBC that the actors would get in the way of the hard-working professionals up there. "The ISS is no place for performers, all sorts of clowns or tourists," he said.

Twisteddoodles *for New Scientist*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Facebook facepalm

When the planet Alderaan is destroyed in *Star Wars*, Jedi master Obi-Wan Kenobi is alerted because he feels a great disturbance in the Force, "as if millions of voices suddenly cried out in terror, and were suddenly silenced". Possibly Facebook founder Mark Zuckerberg had a similar sensation last week, when a technical problem snowballed into the simultaneous collapse of Facebook, Instagram and WhatsApp for 5 hours.

While influencers fretted about how to share selfies and morning yoga routines, the outage led to real problems for firms that use the platforms to do business.

Facebook's malfunction was then compounded by the fact that the firm uses its own systems to carry out basic internal functions, so for a while its software engineers were locked out of a crucial building by electronic door locks. Politicians have for years been asking Facebook to build in back-door access to its systems, although that wasn't quite the kind they meant.

Unorthodox units

As regular readers know, Feedback often muses on unorthodox units of measurement, such as blue whales and "Sydharbs", aka the volume of water that would fill Sydney Harbour. Recently, we highlighted another such unit, the hippopotamus – used by Colin Hester of Queensland's water company Urban Utilities to quantify the mass of wet wipes removed from the city's sewer system each year, in the form of monstrous fatbergs.

Now, honoured by his appearance in this most prestigious of columns, Colin himself has made contact to explain his team's thinking. Feedback is profoundly grateful, because taking a peek under the bonnet of the creative process behind unorthodox units is a rare privilege – we feel like a literature professor discovering a Shakespearean sonnet's first draft.

Hester explains that most people have trouble imagining a cubic metre of water, the definition of a metric tonne, so his team wanted to put the weight of wet wipes into something people could visualise, like an animal.

"The only local candidate appeared to be the crocodile, but over 'smoko' at the treatment plant, we realised that reports of crocs in the sewer might cause alarm," says Colin.

They next discounted birds and hogs in case of confusion with rhyming slang for some of the, ahem, solid matter to be found down in the sewers. Finally, they hit on hippos as the ideal unorthodox unit, not least because they can be large and scary – just like fatbergs.

He adds: "Any small errors in our estimate of the weight of a hippo might be excused because we have only ever seen a picture of one."

Cheekily, he goes on to crowbar into his message a request to share the following with Feedback readers. "Please only flush the three Ps: pee, poo and paper." Got it, Colin. Why, we could almost imagine that drumming up free publicity for this slogan was his intention all along.

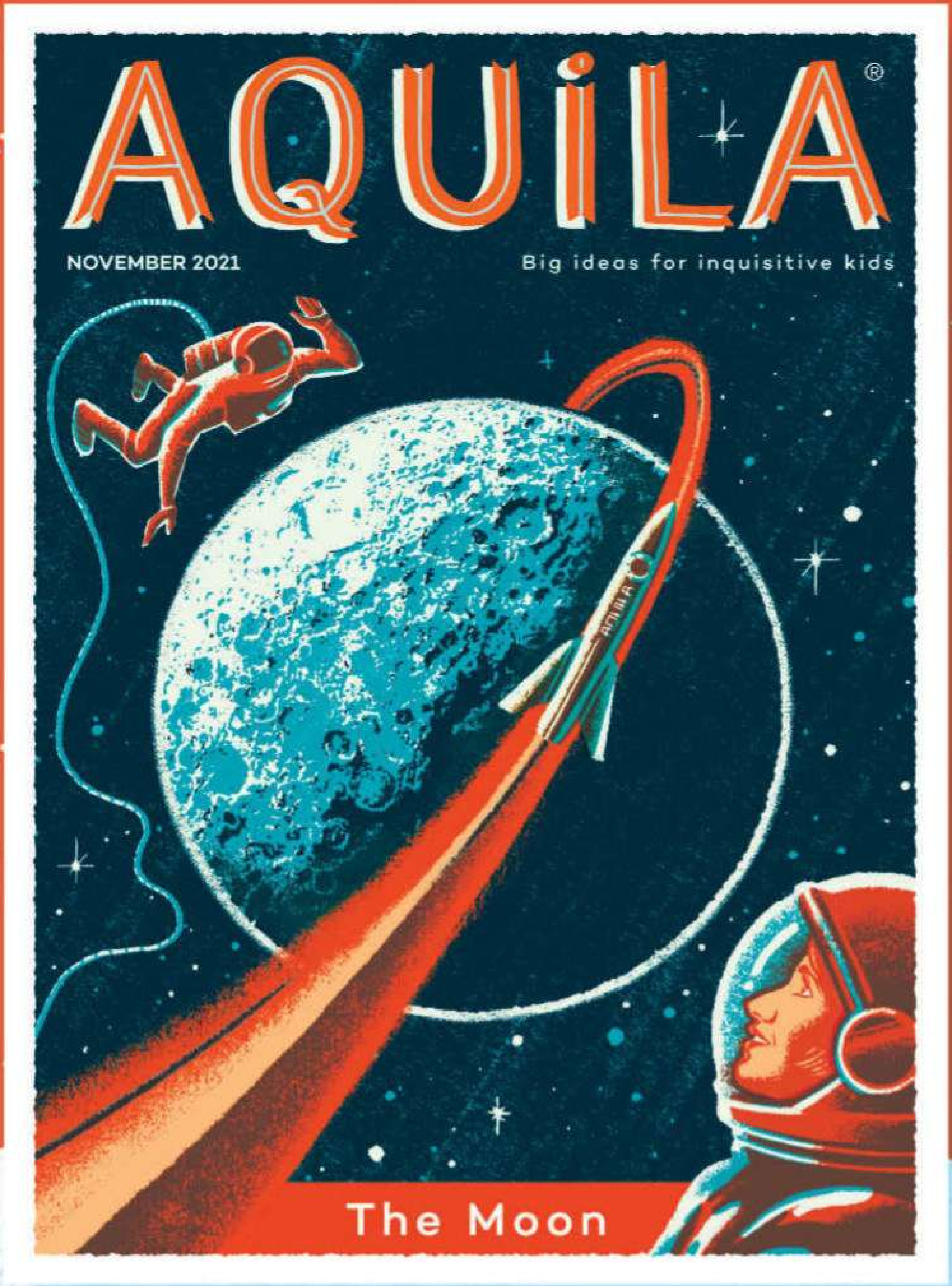
Sinking feeling

Devising unorthodox units is clearly an art form. No less a writer than master storyteller David Sedaris has coined one, in his latest book of autobiographical essays, *A Carnival of Snackery: Diaries 2003 to 2020*, as recently extracted in *The Sunday Times*.

Musing on the improbably large number of spiders in the world, Sedaris informs us that they would collectively add up to 25 million tonnes of arachnids – or 478 times the weight of the Titanic. Thanks to reader Jim Ainsworth for that one.

No explanation is given for why it is helpful to convert the weight of spiders into equivalents of an ill-fated Edwardian-era ocean liner. Urban Utilities's Colin Hester would probably be happier if the amount were expressed in visualisable animals, so for the avoidance of doubt, that makes 7 million hippos. You're welcome. ▮

AQUILA CHILDREN'S MAGAZINE



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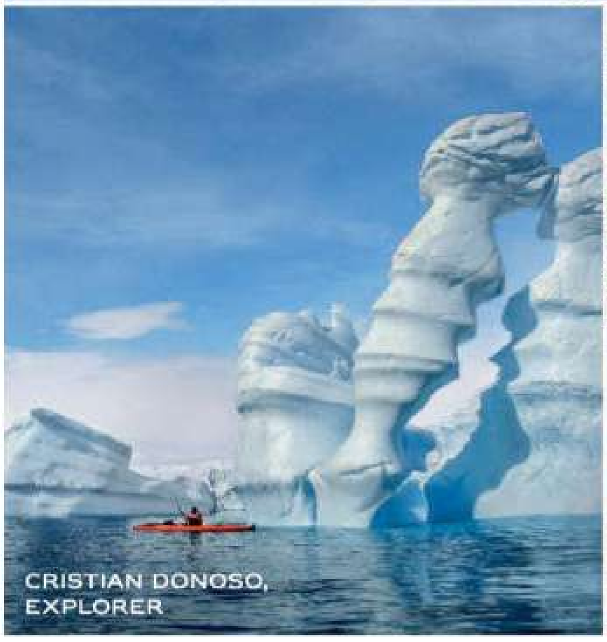

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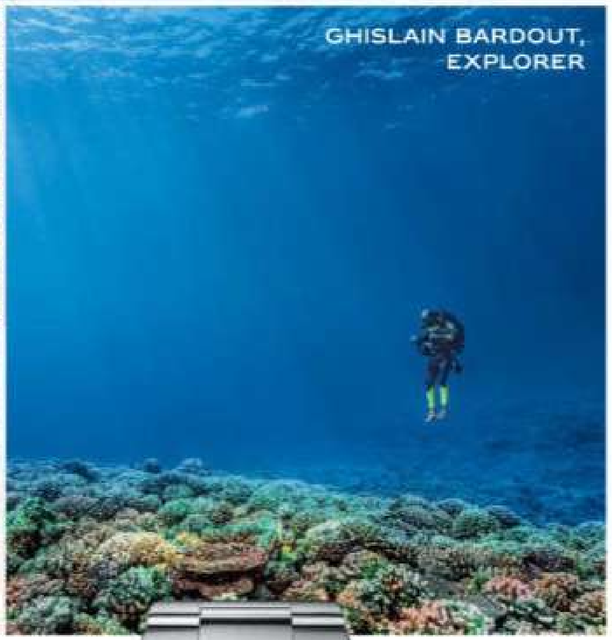

GHISLAIN BARDOUT, EXPLORER

OYSTER PERPETUAL EXPLORER II

WHAT DO THEY SEEK?

Explorers, adventurers, scientists. Men and women who always broadened the horizons, for all humankind to share. Rolex was at their side when they reached the deepest point in the oceans, the highest summits of the Earth, the deepest jungles and both poles. But now that we know, more than ever, that our world has its limits, why do they continue to venture out there, again and again? Certainly not for kudos, accolades, or an ephemeral record. What they truly seek is to understand more intimately how complex and delicate our planet is, to document its change and how together, we can affect it for the better. So as long as they need it, we will be at their side. Because today, the real discovery is not so much about finding new lands. It's about looking with new eyes at the marvels of our planet, rekindling our sense of wonder, and acting to preserve our pale blue dot in the universe… **Doing our very best for a Perpetual Planet.**

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